S·A·E JOURNAL

PUBLISHED BY THE SOCIETY OF AUTOMOTIVE ENGINEERS, INC.

William B. Stout, President — David Beecroft, Treasurer

John A. C. Warner, Secretary and General Manager

Norman G. Shidle, Executive Editor

Vol. 36 — MAY, 1935 — No. 5

CONTENTS

Automobile Racing History Marks Design and Fuel Progress—Frank R. Elliott - - - - - - - - - - - 13

Summer Meeting Interest Soars - - - - 17

Papers from Recent Meetings in Digest 18

What Members Are Doing - - - - - - - 23

T. C. Smith Elected T & M Vice-President for 1935 - - - - - - - - - - 24

Transactions Section Begins

C. F. R. Committee Report on 1934 Detonation Road Tests—C. B. Veal - - 165

Farewell to the Horseless Carriage—Elliott G. Reid - - - - - - - - - - - 180

Cylinder Events Studied in the Logarithmic Diagram—Alfred T. Gregory - - - - - - - - - - 191

Transactions Section Ends

Membership Activities - - - - - - - - - 25

New Members Qualified - - - - - - - - 26

Applications Received - - - - - - - - - 26

Meetings Calendar - - - - - - - - - - - - 27

News of the Society - - - - - - - - - - - 28

Notes and Reviews - - - - - - - - - - - - 38

Publication Office, 56th and Chestnut Sts., Philadelphia, Pa.; Editorial and Advertising Departments at the headquarters of the Society, 29 West 39th St., New York, N. Y. Western Advertising Office, Room 2-136 General Motors Bldg., Detroit, Mich.

The Society is not responsible for statements or opinions advanced in papers or discussions at its meetings or in articles in the JOURNAL.

ROSS PERFORMANCE

Is Not Duplicated

Ross is the only Cam and Lever Steering Gear. Neither the principle on which it operates nor the performance which results, are duplicated. Ross is exclusively a steering institution and its leadership is confirmed by more than two hundred automotive engineering staffs.

ROSS GEAR & TOOL COMPANY • LAFAYETTE, INDIANA

ROSS CAM & LEVER STEERING

Ross assures manufacturers, trade and public these distinctive advantages:

PRODUCT

The cam and lever design, original and exclusive with Ross, makes possible in unequalled degree, these superiorities:

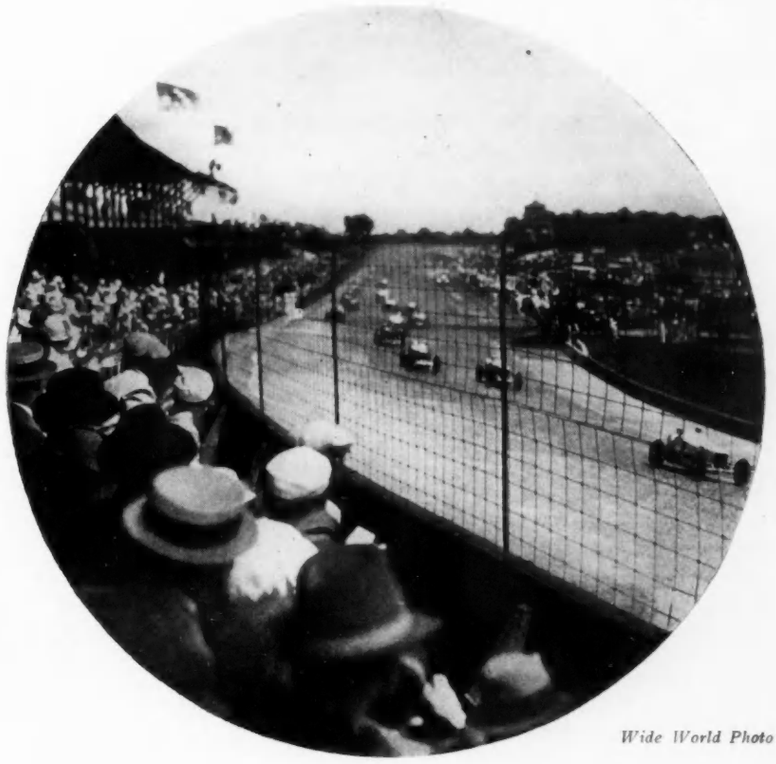
- **EASE**... Ross handles even the heaviest steering load with the greatest ease.
- **RESPONSE**... Ross responds instantly to the slightest wheel pressure.
- **STABILITY**... Ross is irreversible in exactly the right degree—giving a happy combination of stability and road-sense.
- **LONG WEAR**... Ross reduces parts-wear to a minimum.
- **ADJUSTMENTS**... Ross permits, when they are necessary, easier, quicker, more accurate adjustments.

POLICIES

Ross, as an institution, stands for sound, definite policies, as reflected in its product:

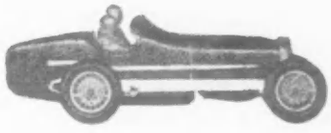
- **QUALITY**... Ross guarantees the very best in materials, workmanship, engineering and inspection.
- **SERVICE**... Ross manufacturing facilities and institutional strength assure a prompt, dependable, permanent source of supply.
- **DEVELOPMENT**... Ross, through continuous engineering effort and research, led its industry to higher standards—and still leads.
- **ADVERTISING**... Ross, through nearly five years of advertising in The Saturday Evening Post is known, accepted, and preferred by car owners.

Automobile Racing History Marks Design and Fuel Progress



Wide World Photo

By Frank R. Elliott
Ethyl Gasoline Corporation



SINCE the early days the race-track has been an experimental station, and the race drivers have been the guinea pigs of the automobile industry.

Ordinarily more can be learned about new developments in tires, steering, balance, ignition, engine design, fuels, etc., in a few hours on the race-track than in months of road testing. If a new feature brings good results during a hard race, we can reasonably expect to see it appear in somebody's production car within four or five years. The Indianapolis race has been the test of all tests because the conditions surrounding this Memorial Day classic make it a real proving ground for everything in the car.

This paper was presented to the Southern California Section of the Society on Nov. 9, 1934.

The Indianapolis Speedway is a brick track 2½ miles in circumference. It was built in 1911 with banks and turns for a contemplated speed of 85 m.p.h. The fastest lap ever turned on the course was slightly over 123 m.p.h. Only moderate repair work has been done since it was first constructed. The track is rough and very destructive to cars. Terrific physical strain is placed on drivers. The continual vibration from running over the bricks literally shakes a car to pieces, and a driver may lose as much as ten pounds in driving the 500 miles of the Memorial Day race.

WITH the 1935 Indianapolis Race scheduled to be run within a few weeks, special interest attaches to this interpretation of the history of that famous race in terms of automobile design changes and automotive fuel developments.

Frank R. Elliott is an S.A.E. member who has more than once driven a car in the 500-mile Memorial Day grind and his article frequently reflects his intimate personal experiences.

In the early days of racing, most of the cars were rebuilt stock cars, equipped with higher rear axle ratios to increase their top speed. But acceleration, then as now, was a very important factor in winning races; so, to stay in the competition, the engines had to be "souped up." This was generally done by using larger carburetors, larger manifold passages and valves, and special camshafts—all with the idea of getting more fuel into the engine. Only a few of the early cars, such as the famous Ford 999, the 120 Fiats, the Blitzen Benz, and some steam cars, were specially built for racing. It was in the Ford 999 that Barney Oldfield first made a mile a minute.

Some of the early car engines were huge even in comparison with modern bus and truck engines, the bore and stroke being sometimes as high as 5½ x 7 in. These large engines could turn up only to about 1000 to 1200 r.p.m., while 1500 to 1800 r.p.m. was considered fast even for the smaller engines. Today, racing engine speeds of between 5000 and 6000 r.p.m. are not unusual.

Tires were quite a problem in the early days of racing, and it was common to use two or three sets in one Indianapolis race. The large cars of the earlier races were quite hard on tires because of their weight, and the poor construction of the tires at the time. It was several years before tire manufacturers were able to produce tires which would stand the punishment of a full 500-mile race.

Early Problems

Many of the early problems were concerned, as in the case of tires, with developing a degree of durability and dependability that would enable a car to finish even at what seems today to be a moderate speed. It was important first of all that the car be kept going. After that came the problem of how fast.

Ability of a car to function continuously has been one of the major goals of the automotive designers, and the developments of design and materials which give our present cars their great dependability are to quite a large extent the by-products of racing.

The changing trends in engine design toward smaller cylinders and higher speeds are imposing greater and greater loads on many of the working parts of engines and, while the direction of these trends has been rather clearly recognized for some years, development limitations have been imposed by lack of ideally suited materials, cooling limitations and the like. The average car owner never suspects the great amount of research in metallurgy and design necessary to produce relatively inexpensive items, such as valve springs, to meet today's conditions in average automobiles. Breakage still is encountered, of course, but generally only after many thousands of miles of operation. How quickly these weaknesses show up under race-track operation is clearly illustrated by an experience which I had while driving in the Indianapolis Race in 1926. I had led the race for many laps and had only 28 laps left to finish, when one valve spring in my engine broke and left me out of the running. The failure of 20 cents worth of material cost me my chance to win the race, which that year would have paid me $10,000. This experience led to changes of design and material which have greatly improved valve-spring characteristics, and which were, to some degree at least, responsible for making possible present higher speeds in automobile engines.

Seeking to trace through the history of racing on the Indianapolis track developments which have established subsequent trends in automotive design, let us glance for a moment at Table 1.

Race Winners

The first race on this track was won with a six-cylinder car; the next seven with four-cylinder cars. Then followed thirteen races in which eight-cylinder cars came through first. The 1934 race was won with a four-cylinder Miller.

In 1920 changes in the race rules included a reduction in piston displacement limits. Consequently, it became necessary to turn out very high horsepower with a very small engine—and the natural way to accomplish this was to increase the engine speed. This could not be accomplished with large cylinders because of inertia forces in the reciprocating parts, and also because of the increasing problem encountered at high speed of dissipating heat in large diameter pistons and valves. The result was use of a larger number of smaller cylinders, a general study of ways and means to hold down inertia forces and critical local temperatures, and research regarding balance in both engines and all other rotating parts of the car. The four-cylinder engine which won the 1934 Indianapolis Race could not have been built to do a consistent 104 m.p.h. in 1920, because the necessary materials and details of design were unknown at that time.

Referring again to balance in rotating parts, its importance becomes apparent when we consider that a wheel only slightly out-of-balance running at 100 m.p.h. exerts a centrifugal force of 500 lb., and is sufficient to lift the wheel and axle off the ground when the heavy side comes up. This causes the front end of the car to dance up and down and makes control very difficult. Most people are familiar with the "wheel tramp" which sometimes develops in passenger cars at high speed due to unbalanced wheels. If a slight error in a wheel turning only about 1200 r.p.m. can produce such a terrific force, it can readily be seen that errors of balance on a crankshaft turning up to 6000 r.p.m. had simply better not be there.

Speeds Varied Inversely with Displacement

It will be noted by referring to Table 1 that, as the piston displacement was decreased, the car speed increased. The contributing factors are worth considering:

(1) With smaller engines, it was possible to make the cars lighter.

(2) With lighter cars, the strain on tires became less.

(3) Drivers do not tire so easily in the lighter cars—it is approximately 25 per cent easier to handle a 2000-lb. car than a 2800-lb. car.

(4) The increased horsepower accrues from the higher rotating speed of the smaller engine.

(5) Due to lighter reciprocating parts in the smaller engine, inertia forces are held down; and, aside from any improvement in materials and design, this enabled the engines to run longer without trouble.

(6) Lubrication troubles were minimized by the improved cooling of the smaller pistons and valves.

Passenger-car design has exhibited a decided trend toward a larger number of smaller cylinders; eight-cylinder models now predominate. Since 1925, the average displacement of passenger-car engines has increased very little—only about 14 per cent, in fact, while the average number of revolutions per minute has gone up over 30 per cent in the same period.

Getting car speed has been one of the two main problems all the while. Many factors in the chassis and body had to be considered. Streamlining to reduce wind resistance received attention early, and with even the improved body lines of today, approximately two-thirds of the horsepower is consumed in creating a disturbance in the air. The rest of the power is used in overcoming friction and in propelling the weight of the car.

Light Weight Advantage

Naturally, a lighter car weight in proportion to the net horsepower is a great advantage since it reduces the amount of power required to overcome friction and car inertia. To provide fair competition and establish automobile racing as a major sport, as well as to enhance the value of its laboratory functions, the Contest Board of the American Automobile Association has at various times promulgated rules governing certain characteristics of the cars which might compete. Weight has been an important feature governed by these regulations, which have been changed from time to time, as seemed advantageous.

The minimum weight at the Indianapolis Speedway was 1400 lb. at the time the 91.5 cu. in. engine was in use. This minimum has been increased, and at present the low limit is 1950 lb. without fuel, oil, or crew. All cars must weigh at least 7 lb. per cu. in. of piston displacement, which, of course, eliminates use of a large engine in a light chassis and provides incentive to get higher efficiency from a small engine.

Every year has seen developments in the horsepower per cubic inch of displacement. Part of this, as already related, has come from higher engine speeds. This has involved an increase in other problems out of all proportion to the increase in speed. Every limiting factor which affects the filling of the cylinders has come in for study and improvement.

Table 1—Indianapolis Race Winners

Year	Engine Make	Piston Displacement Limit	Engine Size of Winner	Number of Cylinders	Average Speed
1911	Marmon	600	447	6	74.59
1912	National	600	490	4	78.7
1913	Peugeot	450	448	4	76.92
1914	Delage	450	380	4	82.47
1915	Mercedes	300	274	4	89.84
1916	Peugeot	300	274	4	83.26
1919	Peugeot	300	274	4	88.06
1920	Monroe	183	182	4	88.50
1921	Frontenac	183	182	8	89.62
1922	Miller	183	181	8	94.48
1923	Miller	122	120	8	90.95
1924	Duesenberg	122	122	8	98.23
1925	Duesenberg	122	121	8	101.13
1926	Miller	91.5	90	8	95.885
1927	Duesenberg	91.5	90	8	97.54
1928	Miller	91.5	90	8	99.48
1929	Miller	91.5	90	8	97.58
1930	Miller	366	151	8	100.44
1931	Miller	366	151	8	96.62
1932	Miller	366	182	8	104.14
1933	Miller	366	258	8	104.16
1934	Miller	365	220	4	104.86

Valve-in-Head Engines Successful

Valve-in-head engines have won every race at Indianapolis since 1913. It has been found that the intake passages with this type of valve are straighter and more direct, and therefore reduce the obstruction to the flow of the fuel and provide higher volumetric efficiency in the high speed range. All of these engines in the winning cars have used overhead cams and, with one exception, even rocker-arms have been eliminated to reduce the weight of the valve mechanism and thereby speed up the valve action.

In spite of the recognized advantages of high volumetric efficiency, overhead valves are employed only to a limited extent in passenger-car design, due largely to the greater difficulty in maintaining silence and partly to the higher production cost. In commercial vehicles and industrial engines, where silence is not so imperative and where operative efficiency offsets added cost, the overhead-valve type of construction is much more generally employed.

Overhead camshafts have been used in cars of more expensive makes, but their great advantage of providing a slightly higher top speed is apparently not yet considered sufficient to justify general adoption in production jobs. Engines do not yet need to be built that way to be fast enough for any practical general use. When and if we need this construction, it is ready.

The Supercharger Era

From 1925 to 1930, superchargers were used in the Indianapolis Race. These added considerable speed to the smaller engines by packing the fuel into the manifold. At top speeds these devices were able to maintain intake manifold pressures as high as 20 lb. per sq. in. They were geared to five times crankshaft speed, to spin up to 30,000 r.p.m. The average size of the impellers was 7 in., and at full speed they had a peripheral speed of about 12 miles per minute. Ball-bearing manufacturers said that it was impossible to meet this problem in these superchargers, and while there were some failures, the performance on the whole was quite satisfactory.

Superchargers have not come into general use in passenger-car engines, as their utility seems to be confined to the high speed range. The simpler means of raising the engine compression ratio provides greater efficiency in the low and middle range, together with a reduction of fuel consumption, a worthwhile reduction of operating temperature without the added first cost or maintenance of a high speed unit.

The supercharger is quite generally employed, however, in conjunction with maximum permissible compression ratio, as a means of getting higher horsepower out of aviation engines. In this case its use seems advantageous, as the problem of manifolding a radial engine to get peak power without manifold pressure is not easy. The problem here, however, is not in any respect comparable to automotive practice.

Rules Changed

In 1930, after the supercharger had been in use for five years, the racing rules were changed to get back closer to stock car practice. The racing cars were enlarged to carry a riding mechanic, the supercharger was eliminated, the permissible piston displacement was raised to 366 cu. in., and the minimum weight limit was increased. Through these various changes it was hoped that the race would be slowed down enough to avoid many of the bad accidents which had been happening, and which had led to severe criticisms. It was also anticipated that stock car entries would be encouraged, which would add greatly to public interest in the results. The latter hope actually has been fulfilled, and it is felt that the results have been very beneficial to the industry. However, speeds have continued to go up. Some of the modified stock cars have been making faster time than the special racing cars of a few years back and have come surprisingly close to the speed of the specially designed racing cars which have been the winners.

Very little thought was given to fuels until 1923. For a long time the customary fuel was just gasoline of about 70 or 72 gravity. This was satisfactory at that time because engine compressions were very low and the carburetors were not much more than mixing valves. Later on a good straight run gasoline with a little cracked stock and 10 to 20 per cent of benzol was all that was required. At that time the compression ratios were running from 6:1 to 7:1, and, due to the small cylinder sizes, no appreciable fuel trouble was encountered. About that time I had a car in which the compression ratio was raised to 8.25:1. By retarding the spark a little and running on selected gasoline it did very well.

Special Fuels

Tetraethyl lead made its appearance on the track in 1924, and from that time on compression pressures were increased, principally by means of the supercharger for the first five years. Already detonation was causing damage, as the extreme pressures caused pistons to crack, and the increased temperature due to detonation caused valves to stick, warp, and burn. By 1926 the use of tetraethyl lead and benzol in order to control detonation was increasing. When the supercharger was eliminated in 1930, compression ratios were immediately boosted. The car which finished second in 1930 had a compression ratio of 10:1. The engine developed 125 hp. with a 7:1 ratio, and 150 hp. with the 10:1 ratio. Compression ratios as high as 13:1 have been used and detonation satisfactorily controlled by special blends of gasoline and tetraethyl lead.

The winners of every race at Indianapolis since 1924 have used lead treated gasoline.

The gasoline used in the past few years has generally been of rather low gravity, with an initial boiling point of 140 deg. fahr., and an end point of 340 deg. fahr. This year a closer distillation range was held in order to get better mileage.

Until 1934 the race rules placed no limit on the amount of fuel that could be used. As it seemed desirable to slow the cars down, however, the AAA Contest Board decided this past year to allow only 45 gal. of fuel for any one car. The 1934 winner used only 35½ gal. of fuel, and an average of 14.1 miles per gal. The winning engine was of 220 cu. in. displacement, or practically the same size as the Ford V-8 and could develop about 160 hp. I believe it is safe to assume that the output of this engine throughout the race averaged about 120 hp. Taking this as a basis for calculation, we find that it used only about 0.42 lb. of fuel per hp. hr. This is better performance than is claimed by the manufacturers of the most efficient aviation engines, which top the list of today's production engines for economical use of fuel.

Comparing fuel consumption figures, it appears that the 1924 winner used from 45 to 50 gal. of fuel for the race, so the 1934 winner used about 20 per cent less fuel in spite of averaging at 6½ m.p.h. faster than did the 1924 winner. The increase in compression played a most important part in both the increase in speed and the decrease in fuel consumption. Likewise, all straight-away records made in the last few years have been made with engines having high compression ratios and using lead treated fuels.

Passing now from racing results to practical applications in passenger automobiles, we find that the speed and power of our cars has undergone a great change in the past few years. Ten years ago, Chrysler was offering a car guaranteed to do 60 m.p.h.—and in those days it was a fairly fast car. At the present time any modern car will tour with ease at 60 m.p.h., and there are cars on the market guaranteed to do 100 m.p.h.

Our present cars cruising at 60 m.p.h. will frequently give more fuel mileage than the cars of ten years ago could give at 40 m.p.h.

Compression Ratios Increase

Prior to 1925 there was a long period when passenger-car compression ratios stood practically still, but since 1925 when the attention of the industry was directed to the possibilities of improved performance through increased operating pressures—which in turn was made practicable by the availability of improved antiknock fuels—the compression ratios have shown a steady increase year after year. In ten years the compression ratio has increased 30 per cent during this period, but the compression pressures have gone up 45 per cent. This added gain in pressure is due to improvements in manifolding and camshaft design, which have given higher volumetric efficiency.

Where compression ratios and octane values will go in the next few years we can only guess. The limit of the power and economy obtainable with any given engine is the detonating point of the fuel that is used in it. We know from both laboratory tests and field experience that increased compression not only provides more power, but that it is also more economical in spite of the higher cost of the fuel necessary to run without detonation. A considerable part of this economy comes from the fact that the high compression engines run cooler than the low compression engines. The high compression engine converts more of the heat energy into power, and leaves less to be wasted through heat losses.

This is clearly demonstrated in commercial vehicle tests which we have run. We have records on truck fleets where an increase from 4.6:1 to 5.6:1 in compression ratio—operating in both cases on fuels that did not detonate—has shown decreases in peak temperatures of 15 deg. fahr. in the water jacket, 20 deg. fahr. in the crankcase, and 150 deg. fahr. in the exhaust.

Summer Meeting Interest SOARS

Many New Features Promise Memorable Meeting for All

SPECIALS

Transportation Review
Augmented version of last year's successful event

International Exhibit
Overwhelming proof of the Society's International Status

Thirtieth-Anniversary Celebration
Historical displays of memory teasing character

Field Day and Daily Sports
Tilden, Bobby Jones, Cunningham, etc., have promised *not* to be present—so you have a chance

THE GREENBRIER

White Sulphur Springs, W. Va.

June 16 to 21, 1935

Reservation Blanks Have Been Mailed

Please Return Your Application Now

Reduced Fares on Railroads

Excellent Airport for Your Plane

S.A.E. SUMMER MEETING
Technical Sessions
TENTATIVE PROGRAM

Sunday, June 16
Business Session
General Session
A real opener for the 30th Anniversary Celebration

Monday, June 17
Transportation and Maintenance
Motor Transportation: What's Its Destination?
Aircraft Engines
Engine Cooling and Cold Weather Starting
Foreign Aircraft Engine Developments
Passenger Car
All about Stresses in Bearing Metals

Tuesday, June 18
Truck, Bus and Railcar
Diesels Applied to Trucks and Buses
Aircraft
Flying Boat Operation
Results of Foreign Lines

Wednesday, June 19
Passenger Car
Looking Ahead in Design
Diesel
Fuel Systems and Performance
Operation of Diesel Powered Vehicles
Tractor
The Tractor Industry

Thursday, June 20
Passenger Car Body
Fundamentals in Design
Fuels and Lubricants
Symposium on Fuel Volatility
General Session
Something you all will want to hear

Friday, June 21
Passenger Car
Suspensions? Yes, and Transmissions, too!
Fuels and Lubricants
What's New in E. P. Lubricants

Papers from Recent Meetings in Digest

HERE are digests of papers presented at recent Section or Regional Meetings of the Society.

* * * *

Some of these papers will be printed in full in the S.A.E. JOURNAL.

Mimeographed copies of *all of them* will be available, until current supplies are exhausted, at a cost of 25 cents per copy to members; and at 50 cents per copy to non-members. Orders for mimeographed copies must be accompanied by remittance and should be addressed to Sessions Secretary, Society of Automotive Engineers, 29 West 39th St., New York.

Baltimore Section Paper

Wednesday, December 5, 1934

Motor-Truck Transportation — Its Development and Future Possibilities—*M. C. Horine, sales promotion manager, International Motor Co.*

THE author reviews the history of motor-truck transportation as a basis for comment upon its development and future possibilities. Progress is noted in the development of the adaptability of commercial vehicles for different kinds and qualities of loads, improved and special-purpose body-design, transportation of bulk materials, refrigeration and other features.

Load factors are discussed, vehicle capability for speed and distance is referred to, and vehicle obsolescence is treated, together with features of operation.

Possibilities of Diesel-engine usage are mentioned. Taxation injustices and other restrictions are stated, as well as some trends in legislation. The author believes that the greatest progress in motor transport in the future will come from voluntary cooperation rather than paternalistic regulation.

Southern California Section Paper

Friday, December 7

Valves for Internal Combustion Engines and Their Related Parts—*P. J. Sampson, general manager, Jadson Motor Products Co.*

THE author first considers the various types of valves: (*a*) the rotary, which is desirable in a certain sense but impractical because of its inherent inability to maintain fits; (*b*) the sleeve valve of the single or double type, based on a reciprocating design and, as such, impractical because of its relative excessive weight; and (*d*) the most commonly used type, the poppet valve, which in a certain sense has almost as many disadvantages as it has advantages, although it is used on over 95 per cent of all four-cycle internal-combustion engines.

The reason for the almost universal use of the poppet valve is that, apparently, it is the best available design from all angles of the valve problem. It is light and small, consequently presenting a low friction problem, and is the most positive type at high speeds and temperatures, particularly under the present-day output-demands.

Excessive or elevated temperatures and their effects on inlet and on exhaust valves are discussed and it is stated that advance in design has come almost entirely from the valve manufacturers themselves. As to valve seats, the latest development is what is known as a composite-construction inserted valve-seat. An outstanding example is the stellite-faced seats, which are extremely corrosion resisting, but present quite a service problem because of the hardness of the face. In the author's opinion spring loads, as generally designed, are insufficient and should be increased 25 to 75 per cent. Instances are cited indicating very definitely that the valve problem in its entirety is one that can be worked out on a much more satisfactory basis than is true at present.

Indiana Section Paper

Thursday, December 13

Steering Safely—*W. K. Creson, chief engineer, Ross Gear & Tool Co.*

IN this discussion of safety with respect to steering units, the author divides the steering system into (*a*) chassis front ends, (*b*) steering gear, and (*c*) the connecting linkage.

The most important factor in the steering of a vehicle is

its free and natural performance when under way. With a desirable and properly geometrical combination of a number of factors, including caster, camber, toe-in or wheel gather, springing and rigidity of frame, it is possible to produce a job which rolls over minor obstacles and "rolls through" changes in terrain without requiring the particular attention of the driver except as to desired change in direction. Such jobs might be called self-steering, and in such instances it is a comparatively simple matter to install a reduction mechanism with suitable connection linkage to make it possible for the driver to easily, and with purely reflex reaction, control his vehicle's direction of motion.

In the reduction mechanism, or steering gear proper, a high-efficiency unit is desirable to lessen fatigue and thereby prevent accidents on long drives and permit travel over difficult highways or in heavy traffic. Steering gears in general will average from 45 to 50 per cent efficiency in transmitting the steering power to the connection linkage. Cam-and-lever steering-gears are now regularly produced with efficiencies from 60 to 75 per cent, depending on type, and have been produced experimentally with 90 per cent efficiency.

The connection linkage between front ends and steering gear has received considerable attention of late. Stickiness caused from unauthorized oiling of rubber sockets, and failure to lubricate metallic joints, is a common source of "wandering" as a steering difficulty. Linkages of high efficiency, with sealed lubrication, and without appreciable lost motion, have been produced; but research and work along this line are recommended.

Northwest Section Paper

Friday, January 11

Automotive Oil—*Sherman W. Bushnell, chief engineer, Automotive Engineering Co.*

THE author states and elaborates the elementary principles of friction, differentiating between solid friction and fluid friction and including a resume of the molecular-attraction theory of friction.

Oils and refining processes are outlined, and the chemistry and classification of oils are summarized. Stability and the "oiliness" of oils are treated, as well as the specifications popularly exhibited as evidence regarding the quality of an oil. Other subjects considered are service changes in oil such as crankcase dilution and the entry of solid matter into oil, such as carbon, gum, oxides, metallic particles and road dust.

Northern California Section Paper

Thursday, January 24

The Supercharger — "What It Is" — *Roy H. Camp, Graham-Paige Motors Corp.*

THE supercharger is a device which supplies power to the feeding of the fuel mixture into the engine cylinders. Instead of making the engine dependent upon its natural pumping or "sucking" action to draw the mixture through the carburetor and into the combustion chambers, the supercharger forces the mixture into them under pressure. The "suction" of the engine is replaced by pressures ranging from one to several pounds.

Under full throttle, the manifold pressures are positive at all engine speeds. Since with a non-supercharged engine a negative pressure (vacuum) ranging from one to several pounds is required to "draw" the mixture into the cylinders, the effect of the supercharger is actually much greater than any gage-pressure reading would indicate. Several pounds of "vacuum" is replaced by several pounds of "pressure"; in fact, approximately twice the amount.

The author states that the supercharger is a logical step in the evolution of the gasoline engine. By forcing larger quantities of fuel into the combustion chamber, the increase in the horsepower of the moderate-sized engine amounts to approximately 47 per cent. Contrary to common belief, cars equipped with superchargers actually deliver better gas mileage than those which are not so equipped. The advantage of the supercharger is that it provides more rapid acceleration and higher road speeds at greater economy than does the same-sized engine without the supercharger.

Northern California Section Paper

Thursday, January 24

How Car Manufacturers Can Cooperate with the Commercial Fleet Operators—*R. W. Martland, Jr.*

THE fact that practically every vehicle is a "compromise" to meet average operating conditions is well known, but it seems reasonable that a greater range of "optional" equipment would solve many service problems that originate primarily because of the inflexibility of standard design. The usual practice of the manufacturer is to wait until the operator encounters trouble and then offer a so-called "campaign" changeover, but by that time the operator has had considerable trouble.

The author advocates that the manufacturers advise fleet operators of available changeovers. Operators not bothered with trouble could ignore this bulletin; those who anticipated trouble could make the change before they had road failures.

Instances of forestalling trouble are cited, but it is stated that the present system of waiting for trouble to happen is, in the manufacturer's opinion, less hazardous to him than is an attempt to forestall trouble by advance information; but, obviously, there is some halfway point between the needs of the fleet operator and the limitations imposed upon the car manufacturer by reason of policy. It seems logical that if the manufacturer and fleet owner could meet on a common ground—and the vehicles be properly campaigned according to latest information—that the saving would be incalculable.

Baltimore Section Paper

Thursday, February 7

Maintenance and Cutting Maintenance Costs—*A. F. McDonald, operating manager, Blue Ridge Lines.*

THE creed of good maintenance, as practised by the author's organization, is "eternal vigilance." The magnitude of this organization's maintenance problems is indicated by the facts that it has 468 employes, operates 121 buses approximately 5,500,000 miles annually over the heavy grades of the Blue Ridge Mountains and the mountain foothills, and uses 1,258,000 gal. of gasoline and 28,600 gal. of oil per year.

The paper details the methods employed as regards personnel, inspections, records, garage and shop equipment, shop practices, and maintenance routine. Special problems that were solved are cited.

For the 12 months ended Dec. 31, 1934, the maintenance of bus chassis and bus bodies cost 2.29 cents per mile, this being 0.17 cents higher than the previous year due to the effect of Code regulations.

Buffalo Section Paper

Tuesday, February 12

A New Idea in Lubrication—*A. W. Burwell, vice-president, technical director, Alox Chemical Corp. and J. A. Camelford.*

TO obtain data on the effect of various substances upon the lubricating ability of oils, a machine was needed which would give accurate, dependable and reproducible results. It was determined that to fulfill all requirements the machine desired should have the following features: It should be *delicate* enough to measure oil-friction to a small fraction of a foot-pound, *sturdy* enough to withstand the higher ranges of pressures normally obtaining in bearings operating in the field, *consistent* enough to permit of running by different operators without important variation of results—different machines should also be able to give the same results on the same oil when run by operators in different parts of the country but under identical conditions of operation—and designed to imitate practical conditions under complete laboratory control.

A survey of the better-known machines used for the purpose at first indicated that an instrument as outlined could not be obtained. Eventually, however, a machine was developed which completely fulfills all the requirements set forth. This machine is called the Lubarometer, indicating an instrument in which the lubricating ability of oils may be studied under varying conditions of pressure and temperature and speed, and the authors describe its uses in testing, giving also data thereby obtained. The paper includes analyses and many data on the general subject of lubrication.

Northwest Section Paper

Friday, February 15

Fleet Maintenance—*W. W. Churchill, superintendent of equipment, Washington Motor Coach Co.*

THE paper concerns the maintaining of intercity motor trucks and motorcoaches, the major problems being the maintenance of the engine, the front axle and the steering system. The maintenance department must satisfy the management regarding reduction of road failures to a minimum, clean, comfortable and attractive coaches, low maintenance cost and low operating costs. Operating costs that can be kept to a minimum by the maintenance department are, tire wear, gasoline and oil consumption and proper maintenance of coach bodies and seats to eliminate the damaging of wearing apparel or injury to passengers.

The main subjects treated are lubrication, inspection and maintenance, body maintenance, and cost recording. Individual cost figures are broken down to cover both labor and material repairs to the engine, chassis, transmission, differential, brakes, body, electrical system and accidents. All of these data are recorded and compiled complete for 90 units by one clerk. At the end of any period, the cost per mile of any unit or part of a unit can be figured. In keeping costs in this manner, if, for example, rear-axle repairs on one particular unit are running too high, the manufacturer should be notified or other steps taken to remedy the situation. The average mileage of gasoline and of oil consumption is computed each month. Units found to be low in either gas or oil mileage are immediately investigated.

Northern California Section Paper

Thursday, February 21

Problems in Heavy Duty Automotive Brake Design and Maintenance—*Norman Leeds, Jr., The Raybestos Division, Raybestos-Manhattan, Inc.*

THIS paper sets forth some of the many problems connected with the design and maintenance of heavy-duty brakes that urgently require solution, together with some indication of the direction from which the solutions may come.

Taking it for granted that experience in the last few years has definitely settled a number of questions in the design of such brakes and their application to heavy-duty vehicles, the assumption is made that satisfactory brakes, on the heavier vehicles at least, should include the following features:

(1) Brakes should be on all wheels, utilizing the entire weight of the vehicle.

(2) They should be of internal construction with hinged shoes of some type.

(3) Power of some sort should be used to obtain the pressures necessary to stop the vehicle with comfortable effort on the part of the operator.

(4) Cast-iron drums, which give the best results so far as known at present.

(5) The friction element should be some kind of so-called "fabricated" material not so hard as the drum and in an easily replaceable form.

Detailed consideration of each of the foregoing five points is then presented, and a summary covering 10 desirable features for heavy-duty brakes is appended.

Northern California Section Paper

Thursday, February 21

Our Accident Prevention Methods—*James Reed, superintendent, City Ice Co.*

THE paper cites the safety program devised and promulgated by the City Ice Delivery Co., a combination of three major ice companies in San Francisco.

Membership in the National Safety Council was secured and an effort made to cause the company's personnel to become "safety conscious". Safety posters were displayed in conspicuous places in the company's properties to help build up this necessary consciousness, and a metal holder carrying a card bearing a safety message was placed on the dashboard of each truck. Drivers were encouraged to compete for the "No-Accident Driver" awards, presented by the National Safety Council each year.

An order was posted notifying all employes, including executives, to report in person to the general office when they became involved in an accident. Thus, the causes of accidents were investigated and the responsibility for each was ruled upon. Maintenance of equipment was intensified, the result being that not more than 2 per cent of the company's accidents are caused by mechanical failures.

For the years 1930 to 1934, inclusive, an average of 73 accidents per year was reported; there being 109 during 1931 but only 34 during 1934. *Education, cooperation,* and *firmness* and *fairness* toward the employes on the part of the management have been the watchwords.

Chicago Section Paper

Tuesday, March 5

Economical Operation of Motor Trucks—*Pierre Schon, transportation engineer, General Motors Truck Co.*

THE operating cost of motor-vehicles can be reduced if shop mechanics are better acquainted with manufacturers' service manuals and instruction books, according to the author. Design changes are constantly being made on motor vehicles and auxiliary appliances and accessories are improved from year to year. In order for mechanics and shop foremen to keep abreast of these changes, careful study of manufacturer's instruction books and service manuals is highly essential whenever a new type of vehicle is added to a fleet.

One of the most vexing problems for truck manufacturers is the prevention of misapplications of equipment, the author states. Perhaps we will see laws enacted by the various states regulating payload and gross weight according to engine power and brake stopping ability, he continues.

Some of the main subjects treated are selection of equipment, load distribution, truck and trailer operating costs at various mileages per day, tires, maintenance and repairs. Preventive maintenance is advocated.

Regarding the use of regular furnace-oil in automotive engines, the statement is made that, as yet, it cannot be considered as a substitute for gasoline. A further statement is made that perhaps the most promising aspect of the fuel question, from the operators' standpoint, lies in the development of the Diesel engine for motor vehicles.

All of the subject matter is treated in great detail, and the paper is replete with tabulated and other data.

Metropolitan Section Paper

Monday, March 11

Carbon Monoxide in Moving Vehicles — *F. M. Van Deventer, Cities Service Co.*

THE paper reports upon the results of a highway investigation which justifies the conclusion that carbon monoxide in exhaust gases can and does seep into the passenger compartments of moving vehicles in sufficient quantities to impair the judgment of the driver in the control of his car; analyzes the cause factors resulting in the existence of carbon monoxide within cars; and recommends a form of inspection and maintenance which will effectively reduce, if not eliminate, this hazard to public safety.

Highway tests were made with the cooperation of the State police and motor-vehicle authorities in seven New England and Eastern states, several hundred cars being picked at random from State highways by the State police and examined, and between 5 and 6 per cent of the units tested were found to contain dangerous quantities of carbon monoxide in the passenger compartment.

It was found that there were five forms of infiltration to account for the presence of carbon monoxide within cars: Trailing eddy-currents, pick-up following another car, exhaust leaks, exhaust-manifold heaters, and crankcase breather-pipes. It was found that all dangerous concentrations of carbon monoxide could be attributed to a combination of two or more of the three factors: (*a*) low combustion efficiency, which results in an excessive proportion of carbon monoxide in the exhaust gases; (*b*) a leak in the exhaust system; and (*c*) openings in the floor boards or other parts of the body shell.

Other phases of the subject are treated under the headings: Remedial procedure, asphyxial cases, comments on the foregoing, accident cases, general conclusions and recommendations.

Buffalo Section Paper

Tuesday, March 12

Rubber and Its Uses in Transportation—*Arthur W. Bull, Development Department, United States Rubber Products, Inc.*

THE paper presents a review of the sources of rubber, its characteristics and the methods used in manufacture, discusses the wide range in properties obtainable from different forms of rubber, and describes a considerable number of applications in which the different properties of rubber are made use of. It is stated that tires and tubes consume about 80 per cent of the rubber used in the United States. The complex structure of tires is explained, many uses and advantages of rubber in the automotive and aircraft industries are enumerated, as well as in industry in general, and combinations of rubber with other materials for special purposes are mentioned. The disadvantageous features of rubber are cited also.

The significant properties of rubber are listed as follows:

Great range in properties obtainable; soft to hard rubber
Stretch; very high, or low, if reinforced with fabric or metal
Tensile strength
Flexing endurance; withstands large distortions without injury
High capacity to absorb energy
Hysteresis; provides self-damping
Resistance to chemicals very good
High abrasive resistance; better than steel, especially when wet
High dielectric strength
High coefficient of friction
Waterproof
Readily molded
Can be given any color

Northwest Section Paper

Friday, March 15

High Output Engines and Fuels—*Howard A. Reinhart, Ethyl Corp.*

THE author does not set forth any definite theories, but touches on theory in general, and shows how theories promulgated by various research men and authors (even though many of them disagree) have been responsible for tangible results and improvements in the present high-output Otto-cycle engine.

The main subjects treated are the principle of combustion, engine design, theoretical comparisons of ideal Otto-cycle engines, supercharging, and practical aspects.

Difficulties experienced in the design of high-output engines are cited. In conclusion, the author states that, with the gradual improvement in metallurgy, design improvement based upon better knowledge of flame propagation and the better understanding and use of instrumentation in the field will greatly add to the efficiency of the Otto cycle. Further, that with the radical, fundamental changes, such as solid injection and the possibilities of a variable-compression engine controlled by M.E.P., who knows but what the race

between the Otto cycle and the Diesel cycle will still be won by the former, as it has been definitely proved in the laboratory that the Otto cycle, from a thermal efficiency standpoint, is more efficient than the Diesel cycle, even though at this time it does not readily lend itself to production.

Detroit Section Paper

Monday, March 18

How the Design of Some Motor Parts Can Influence Piston-Ring Performance—*J. H. Ballard, sales and service engineer, and N. A. Moore, assistant general manager, Sealed Power Corp.*

IN pointing out how other engine parts can influence piston-ring performance, the author states that the only sound way is for the engine designer to compromise wherever necessary, aiming always to arrive at the best average performance from all related parts. To do this intelligently, the ideal design for each part should be understood, and then these ideals should be deviated from only enough to obtain satisfactory coordination throughout the entire engine.

In view of the intimate relationship which exists between the piston and the rings, these two parts must be considered as an operating unit. Heat dissipation is a vital factor of piston design. A piston must be designed so that it will resist the thermal and mechanical forces which tend to distort it, otherwise it cannot operate properly as a piston, and if it does not perform this part of its function, it must necessarily fail as a ring carrier.

Other factors influencing design and performance are cylinder-bore distortion, ring scuffing, and foundry practice. The machine shop controls the flatness of piston rings, their ability to conform tightly to a round barrel, their shape and, particularly, their radial-pressure characteristics.

Detroit Section Paper

Monday, March 18

A Study of the Efficiencies of Overdrive Units Used in Passenger Cars—*W. A. Gebhardt, Case School of Applied Science.*

DURING the last few years there has been a definite trend in passenger-car design toward high-speed, moderate-sized engines. This has resulted from the endeavor of car designers to obtain a low weight-horsepower ratio. The public is demanding rapid acceleration and also high sustained speed for open-road driving.

To adapt the moderate-sized high-speed engine to these demands, the engineer has been obliged to adopt a rather low rear-axle ratio to satisfy "performance" requirements and to depend upon high engine speeds for fast open-road driving.

Two devices have been developed recently in an attempt to overcome the disadvantages of high-speed engines and other difficulties. Each—ordinarily called an "overdrive"—embodies a system of planetary gearing arranged so that it receives power at a certain speed and torque and transforms it into a higher speed and lower torque. One device incorporates the overdrive feature in the rear axle; the other is installed as a separate unit directly behind the transmission.

The paper represents a study of the efficiencies of the two designs and a determination of the sources of loss. Numerous tests are described and illustrated, and many data are presented and analyzed.

Syracuse Section Paper

Monday, March 25

Operation and Maintenance—*J. F. Winchester, manager, general automotive department, Standard Oil Co. of New Jersey.*

AFTER rather extensive general consideration of the history of the automotive industry concerning its growth, its status in relation to the railroads, and the subjects of taxation and restrictive regulation of motor-vehicles, the author points out some of the factors that create a wide variety of operating costs, presenting also comments and illustrations pertaining to operation and maintenance.

The author advocates the promulgation of a definite understanding that, regarding the machinery of a motor-vehicle, it is continuously wearing out. What may be a safe vehicle to operate today may shortly become worn to such an extent that it will become unsafe to operate. The machinery of vehicles therefore should be inspected periodically to promote longer life, safety in operation, economy of material, and fewer days lost from service.

Materials of construction are considered; different phases of the maintenance problem are stated, some in detail. Technical considerations and subjects such as repair-shops, the duties of the management personnel, and general operation and maintenance policies applied to the laying of an oil pipeline across the Syrian Desert, are set forth at length and illustrated.

Washington Section Paper

Monday, April 1

The Future of the Autogiro for the Private Flyer—*Agnew E. Larsen, Autogiro Co. of America.*

THE paper deals with the Autogiro's place in the future of private flying. The author states that he has long been convinced that private flying would never become widespread until and unless a type of heavier-than-air craft should be developed that would be free from the inherent limitations of the airplane. Reduced to mere generalities such a machine must possess two characteristics. First, unfailing sustentation and satisfactory stability which do not disappear with the cessation of forward speed. Second, the ability to operate both in taking off from and alighting within areas much more restricted than that which the airplane requires. With these requirements in mind he believes that the Autogiro represents the principle of flight which is ideally suited to private flying.

The history of the Autogiro is outlined and its development commented upon, noteworthy features of present design being the location of the engine at the rear of the passengers with power transmission to a gearbox on the nose which will serve the dual function of propeller and rotor transmission unit. At the same time, this rear location of the engine affords, for the first time, the possibility of a really simple transmission to the rear wheel which will enable the realization of the highly desired performance of roadability. This feature will permit the landing and take off of such an Autogiro in virtually any small plot of ground, and at the same time enable the private flyer to shuttle his craft from his point of departure or destination down any thoroughfare to a point of storage.

What Members Are Doing

D. F. Myers, formerly technical advisor, Cathay Motors, Ltd., Shanghai, China, has been named advisor to the Trust Department of the Central Bank of China. This bank, controlled by the Chinese Government, has charge of all purchasing of automotive equipment for the Chinese National Army.

Maurice Hanna, formerly automotive electrician, Storage Battery Supply Co., Seattle, Washington, now operates the Maurice Hanna Auto-Electric & Carburetor Service.

R. T. Haslam has been appointed general sales manager for Standard Oil Companies of New Jersey, Pennsylvania and

R. T. Haslam

Louisiana and the Colonial Beacon Oil Co. He was formerly vice-president, Standard Oil Development Co., New York City.

A. H. D'Arcambal, sales manager and consulting metallurgist, Pratt & Whitney Co., Hartford, Conn., was to have presented a paper entitled "A Practical Talk on the Machinability of Metals," at the April 11 meeting of the American Society of Tool Engineers, at the Fort Shelby Hotel, Detroit.

Walter F. Roeming, formerly draftsman, Murphy Diesel Co., Ltd., Milwaukee, is now draftsman, Buda Co., Harvey, Ill.

Robert K. Jack, consulting engineer, Lansing, Mich., is now connected with the Motor Vehicle Corp., Lansing, as engineer.

D. S. Harder has joined the Fisher Body Corp., Detroit. He was formerly connected with the E. G. Budd Mfg. Co., Philadelphia, as works manager.

Charles F. Kettering, vice-president, charge of research, General Motors Corp., was scheduled to speak at the annual American Association of Advertising Agencies dinner, held at The Greenbrier, White Sulphur Springs, W. Va., on Friday, April 12. The dinner program was a highlight of the annual convention held April 11 to 13.

William J. O'Neil has been appointed general manager of Dodge Brothers Corp. He was formerly vice-president in charge of manufacturing for the same company.

William O. Charles, formerly president and general manager, Dallas Motors Inc., Dallas, Texas, has become connected with the Community Motors Inc., New Orleans, as Pontiac sales manager.

H. D. Church, formerly vice-president in charge of engineering, Winton Engine Co., Cleveland, is now connected with the General Motors Corp., Detroit.

H. D. Church

Stephen J. Zand, aeronautic research engineer, Sperry Gyroscope Co., Brooklyn, N. Y., returned from France on the Majestic, April 7.

Charles J. Martin is now sales engineer, Ex-Cello Aircraft Co., Detroit. He was formerly chief engineer, F. Coleman & Sons, Detroit, Mich.

H. R. McMahon, president, Standard Steel Spring Co., Coraopolis, Pa.; *H. E. Figgie,* vice-president, Standard Steel Spring Co., *D. T. Gleason,* works manager; and *J. M. Schoonmaker, Jr.,* were elected to the Board of Directors of the Standard Steel Spring Co., at the stockholders meeting on April 1. Mr. McMahon and Mr. Figgie were re-elected president and vice-president and Mr. Gleason became a vice-president of the company.

Robert S. Merithew is now with International Business Machines, Endicott, N. Y. He was formerly with M. & M. Motor Sales, Inc., Norwich, N. Y.

Joseph Geschelin

Joseph Geschelin, engineering editor of *Automotive Industries,* Philadelphia, has been named field editor of the Chilton Co. at their office in Detroit.

F. Landgraf is connected with the Mechanical Development Co., Denver, Colo., and is also chief engineer of The Lewis American Airways, Inc., Denver.

Maurice Stubnitz is now president of the Stubnitz-Greene Spring Corp. at Adrian, Mich.

Louis J. Heinrich has been made sales representative on fleet accounts of the Autocar Sales & Service Co., New York City. He was formerly district service manager for the same company.

A. B. Boehm has become manager of lubrication sales for the above companies. He was formerly assistant manager, lubrication sales, Standard Oil Co. of New Jersey, New York City.

John Pollitt, Jr., is now service manager of Wilmot Breeden Ltd., of Camden Street, Birmingham, England. He was formerly with Joseph Lucas, Ltd.

Beppe V. Romersi has joined the Societa Anonima Fiat's office in Detroit as mechanical engineer.

S. Ward Seeley has joined Lord & Thomas, Inc., New York City. He was formerly with N. W. Ayer & Son, Inc., Philadelphia.

Clarence H. Schildhauer is now with Pan American Airways at Alameda Airport, Alameda, Calif. He was formerly with Pan American in New York City.

George F. Downing is now maintenance superintendent for the Z. & M. Coach Co., Inc., Flushing, N. Y.

Julius Kuttner

Julius Kuttner, formerly editor of *Diesel Power,* and recently connected with International Harvester Co., Chicago, has joined Fairbanks, Morse & Co. as research engineer.

M. F. Feather has become associated with the Austin Trailer Equipment Co. of Muskegon, Mich. He was formerly sales engineer, Blood Bros. Machine Co., Allegan, Mich.

E. N. Earman, formerly automotive engineer with the National Carbon Co., New York City, is now service and mechanical representative with the Chevrolet Motor Co., Chicago.

F. A. Riegel, formerly supervisor of claims, Chevrolet Motor Co., Bloomfield, N. J., is now with General Motors Export Co., New York City.

Arthur H. Williams, formerly chief engineer and production manager, Shafer Bearing Corp., Chicago, has been appointed factory manager and general superintendent of the Cleveland Automatic Machine Co., Cleveland, Ohio.

Fred N. Burlew is now draftsman with The Northrop Corp., Inglewood, Calif. He was formerly in the stress analysis department, Curtiss Aeroplane & Motor Co., Inc., Buffalo, N. Y.

Amos K. Munson, formerly engineer of construction, United Traction Co., Albany, is now purchasing agent of the above company and also of the Capitol District Transportation Co., Inc.

Carl Tiedemann is now connected with the Argonaut Aircraft Co. as junior engineer. He was formerly engineer, Chance Vought Aircraft Corp., E. Hartford, Conn.

Frank L. Morse

Frank L. Morse, president of the Morse Chain Co., died at Orlando, Fla., on March 25, at the age of 70.

Mr. Morse, with his brother, was the founder of the company which bears their name and which now operates plants in Ithaca, N. Y., and Detroit, as the subsidiary of the Borg-Warner Corp., of which Mr. Morse was a director.

About four years ago he relinquished active direction of business and subsequently resigned his S.A.E. membership. He was for many years a well-known figure in the automotive industry and active in the affairs of the Society.

Charles L. Lee

Charles L. Lee, research engineer for the Inland Mfg. Co., Division of the General Motors Corp., and treasurer of the Dayton Section of the Society, died recently at the age of 65, after an illness of three months' duration. Mr. Lee had been associated with Charles F. Kettering in numerous engineering developments and it was said that his name could be linked with nearly a thousand inventions developed for such diversified companies as National Cash Register, General Motors and Remington Arms.

As early as 1900 he had built an automobile but shortly afterward he threw in his lot with Mr. Kettering at National Cash Register and continued his connections with that company extending over thirty years.

Referring to Mr. Lee's death, C. S. McCann, chairman of the Dayton Section, writes: "We will feel this loss here very much indeed, as I cannot say too much in favor of Mr. Lee's fine character and wonderful ability as an engineer".

Three of Mr. Lee's four surviving sons are connected with the automotive industry: Ralph Lee, with General Motors Corp., Detroit; Forest Lee, in the research department at the Inland Mfg. Co.; and Kenneth Lee, director of research for the Chrysler Corp.

Dr. Masakazu Negishi

Dr. Masakazu Negishi, technical advisor for the Miyata Works, Ltd., in Tokyo, and a foreign member of the Society since 1917, died Jan. 21, at his home in Japan after a sudden illness.

T. C. Smith Elected T & M Vice-President for 1935

THE special election held to fill the vacancy in the office of Vice-President representing Transportation and Maintenance Engineering for 1935 resulted as follows:

T. C. Smith	**324 votes**
F. C. Patton	**273 votes**

Closure of voting was on April 15 in accordance with the procedure for holding this special election outlined in the resolution passed by the Council on Jan. 7, 1935, and printed in full on pages 26 and 27 of the February, 1935, issue of the S.A.E. JOURNAL. Tellers of election were A. D. T. Libbey, F. C. Mock and Herbert Chase.

In accordance with the regulation governing the special election, Mr. Smith assumes office immediately.

T. C. Smith

Temple C. Smith, who has been elected vice-president of the Society for 1935 representing the Transportation and Maintenance Engineering Activity, is engineer, motor-vehicles and construction apparatus, for the American Telephone and Telegraph Co.

Mr. Smith joined the Society in 1924 and since 1929 when he was elected treasurer of the Metropolitan Section has been a member or chairman of many important committees. In 1934, for example, he was a member of the Transportation and Maintenance Activity Committee, the Research Committee, the Crankcase Oil Stability Subcommittee, the Cooperative Committee on Motor-Truck Impact Tests, cooperating with the Bureau of Public Roads and the Rubber Association of America and the Motorcoach and Motor-Truck Division of the Standards Committee, besides being chairman of the Operators Group of the Extreme-Pressure Lubricants Subcommittee and chairman of the Highways Subcommittee, cooperating with the Rubber Association of America and the U. S. Bureau of Public Roads.

At the present time, besides his committee memberships, Mr. Smith holds office as vice-chairman of the Metropolitan Section for Transportation and Maintenance.

Since taking his degree in mechanical engineering from Purdue University in 1910, Mr. Smith has been associated almost continuously with the telephone industry and its transportation problems.

C. F. R. Committee Report on 1934 Detonation Road Tests

By C. B. Veal

Secretary, Cooperative Fuel Research Committee

EVER since the adoption of the C.F.R. Motor Method by the Cooperative Fuel Research Committee on Sept. 12, 1932, periodic checks have been made of the reproducibility of this method. To secure correlation with ratings obtained by this road-test method modifications were made in the laboratory method, which had been evolved by the committee and has been since known as the "research" method.

The object of the 1934 C.F.R. detonation road tests, was (*a*) to check the validity of correlation between road knock-ratings and laboratory knock-ratings, and (*b*) to indicate promising paths of research directed toward better mutual adaptation of fuels and engines.

The paper reports on materials and equipment, road-test procedure, supplementary test methods, special reference fuels and results, engine severity-factor and factors affecting fuel-engine relationships. Detonation research is reported upon, and C.F.R. road-test-method specifications are stated in the Appendix.

THIS paper is designed to set forth the important phases relative to motor-fuel detonation of the Cooperative Fuel Research, in which participate the Automobile Manufacturers Association, the American Petroleum Institute, the National Bureau of Standards and the Society of Automotive Engineers, since the last similar report made at the Society's 1933 Annual Meeting[1]. Brief reference will be made to activity in the field of laboratory testing, while most of the discussion will be devoted to the 1934 Detonation Road Tests, to the planning of which were devoted much of the Committee's thoughts along the lines of detonation. The Cooperative Fuel Research also included a project dealing with the detonation characteristics of aviation gasolines, which is the subject of a separate report made at the 1935 Annual Meeting.

[This report was presented at the Annual Meeting of the Society, Detroit, Jan. 18, 1935.]

[1] See S.A.E. JOURNAL, March, 1933, p. 105.

Cooperative Laboratory Detonation Testing

Ever since the adoption of the C.F.R. Motor Method by the Cooperative Fuel Research Committee on Sept. 12, 1932, periodic checks have been made of the reproducibility of this method. The first of these was made within a month following the action above referred to, when the Detonation Subcommittee made arrangements for the sending of three special fuel samples to all of its members and to others equipped for making knock ratings, for the purpose of making independent laboratory ratings which might be checked against one another. On May 8, 1933, the Detonation Subcommittee appointed a special subcommittee, with H. F. Huf as Chairman, to circulate another series of test fuels for an inter-laboratory check on the motor method. A third series of such tests was made later in the year, in answer to an informal request of the Division of Refining of the American Petroleum Institute, including as participants all owners of C.F.R. engines who wished to participate. Early this year Mr. Huf submitted to Committee D-2 of the American Society for Testing Materials, on behalf of the Detonation Subcommittee, a report on the reproducibility of the tentative method of test for knock characteristics of motor fuels.

Following this preliminary series of tests, periodic cooperative reproducibility check tests were made a function of the Detonation Subcommittee, by action of the Cooperative Fuel Research Steering Committee at its meeting on Jan. 26, 1934. These check tests are conducted by a sub-subcommittee, the membership of which is voluntary and limited to the members of the Cooperative Fuel Research Committee and the Detonation Subcommittee. This organization has come to be known as the C.F.R. Monthly Exchange Group; the tests include three samples sent out each month; a different laboratory assumes each month the expense and responsibility for sending out the samples.

Origin of 1934 C.F.R. Detonation Road Tests

In 1932 the C.F.R. road-test method was developed and, to secure correlation with ratings obtained by it, modifications were made in the laboratory method, which had been evolved by the Committee and has been since known as the "research" method. The resulting C.F.R. motor method was subse-

Table 1—Description of Non-branded Fuels

C.F.R. Code	Uniontown Code	
b-1	12	Cracked gasoline
b-2	5	Cracked gasoline
b-3	10	b-1 plus third-grade gasoline for 65 octane No.
b-4	8	b-2 plus third-grade gasoline for 65 octane No.
b-5	2	b-3 plus tetraethyl lead for 70 octane No.
b-6	9	b-4 plus tetraethyl lead for 70 octane No.
b-7	11	b-2 plus tetraethyl lead for 75 octane No.
b-8	7	Third-grade gasoline plus benzol for 70 octane No.
b-9	15	California straight-run gasoline

quently adopted by the American Society for Testing Materials as Tentative Method of Test for Knock Characteristics of Motor Fuels (A.S.T.M. designation D 357-33T), March 7, 1933.

The Cooperative Fuel Research Committee definitely recognized the possibility that the motor method would require revision from time to time as improvements in engine design and fuel characteristics outmoded its provisions; and, in adopting the method, provided for annual consideration of revision. Such consideration, in the fall of 1933, led to the appointment of a special committee to formulate a program; and, finally, after several meetings of the interested committees and constructive revisions of the original draft, a program was arrived at, and the detonation subcommittee was authorized to carry it out by action of the Cooperative Fuel Research Committee at its May 1, 1934 meeting.

General Purpose and Participation

The object of the 1934 C.F.R. detonation road tests, as stated in the approved program, was:

(1) To check the validity of correlation between road knock-ratings and laboratory knock-ratings.

(2) To indicate promising paths of research directed toward better mutual adaption of fuels and engines.

Participants were to include any organization in the United States willing to share both the work and expense involved in providing cars, equipment, and supplies, together with representatives of foreign countries. Accordingly, invitations were extended to the companies in the oil, automotive, motor-truck, engine, and allied industries in this country, and to the Office Nationale des Combustibles Liquides, of France, to the Institution of Petroleum Technologists of Great Britain, and to the National Research Council of Canada.

Twenty-five organizations and 44 individuals participated in the 1934 C.F.R. detonation road tests, almost twice the number in the 1932 project. Details of personnel, organization, and the sources from which were met the expenses involved in carrying out the test program have been set forth in a previous account[2].

Materials and Equipment

(1) *Fuels.*—(*a*) *Test Fuels.*—The following fuels were used: 300 gal. each of eight branded fuels obtained from sales warehouses of the manufacturers, representative of the motor fuels sold throughout the country; and 250 gal. each of nine experimental or non-branded fuels, chosen to represent different types of refinery products.

(*b*) *Reference Fuels.*—The reference fuels used were A-3 and C-8, supplied by the Standard Oil Development Co. In rating fuels beyond the octane-number range of blends of these fuels, lead tetraethyl was added to C-8. Descriptions of the non-branded fuels are given in Table 1. The inspection data on all the fuels are set forth in Table 2.

(2) *Cars.*—In Table 3 are listed the 1934 cars used, including engine specifications. The selection of cars was based principally on sales volume. In view of the preponderance of the three low-priced cars, three of each of these cars were included to give weighting to the final road octane value. The Graham car was used to give results indicative of possible future developments in higher compression ratios and supercharging. Four of these cars are sold with optional cylinder heads. These heads were used to extend the octane-number requirement of these cars. It was required that all test cars supplied by the participating companies be in normal mechanical condition, adjusted to factory settings; and that they have a minimum of 1500 miles of operation since the last removal of combustion-chamber carbon.

(3) *Location.*—After consideration of several other possible locations for the road tests, the Uniontown Hill, near Uniontown, Pa., was again selected as the most suitable for

[2] See S.A.E. JOURNAL, September, 1934, p. 13.

Table 2—Inspection Data on Branded and Non-branded Fuels

Fuel	Gravity, Deg. A.P.I.	A. S. T. M. Distillation, Deg. Fahr. Initial Boiling Point	10	20	30	40	50	60	70	80	90	Maximum	Loss, Per Cent	Recovery, Per Cent	Reid Vapor Pressure, Lb.
1	60.2	96	136	164	192	220	242	267	290	318	357	408	2.2	96.7	9.2
3	57.8	102	149	179	206	232	254	277	299	324	353	396	1.5	97.5	7.2
4	61.0	103	151	180	202	223	242	262	284	309	340	386	1.7	97.3	7.5
6	60.9	96	140	173	202	226	246	268	292	318	354	402	2.4	96.7	8.8
13	61.4	105	145	168	184	212	232	260	284	316	354	398	1.2	97.8	7.0
14	60.8	102	152	190	221	246	268	290	311	332	354	390	1.7	97.3	7.1
16	59.2	100	146	180	210	234	254	276	296	320	352	412	1.7	97.2	7.5
b-1	54.6	96	137	168	198	229	260	290	316	345	370	398	1.8	97.2	8.7
b-2	57.7	97	142	174	212	240	265	290	314	342	372	408	2.0	97.0	8.2
b-3	57.4	97	141	174	205	235	262	288	314	338	364	395	1.8	97.2	8.2
b-4	57.6	100	146	184	216	244	267	291	315	340	368	408	1.7	97.2	7.4
b-5	57.2	98	142	176	208	236	264	290	314	340	364	394	2.0	97.0	8.1
b-6	57.6	100	147	183	216	242	267	291	314	340	370	406	1.6	97.3	7.6
b-7	57.0	98	146	182	213	242	266	290	315	341	370	409	1.8	97.2	8.0
b-8	46.4	126	166	176	183	189	196	209	238	298	338	381	1.0	97.9	6.0
b-9	57.4	100	149	182	208	228	244	262	283	310	351	415	1.9	97.1	7.6
A-3	62.8	146	191	210	224	236	246	258	271	235	306	368	1.0	98.0	3.5
C-8	63.9	124	160	170	178	185	192	201	212	227	257	328	1.1	98.0	5.9

Table 3— Engine Data and Specifications of Test Cars

Car	Bore and Stroke	Displacement	Cylinder-Head Type and Material	Compression Ratio	Standard Spark Setting
Buick	3 3/32 x 4 5/8	278.1	I-C.I.	5.25	11 deg. B.T.C.
Cadillac	3 3/8 x 4 15/16	353.0	L-C.I.	6.25	9 deg. B.T.C.
Chevrolet	3 3/16 x 4	206.8	I-C.I.	5.45	10 deg. B.T.C.
Chevrolet	3 5/16 x 4	206.8	I-C.I.	5.45	10 deg. B.T.C.
Chevrolet	3 5/16 x 4	206.8	I-C.I.	5.45	10 deg. B.T.C.
Chrysler	3 1/4 x 4 1/2	298.6	L-AL	6.5	6 deg. A.T.C.
Dodge	3 1/4 x 4 3/8	217.8	L-C.I.	5.5	2 deg. A.T.C.
Dodge	3 1/4 x 4 3/8	217.8	L-AL	6.5	4 deg. A.T.C.
Ford	3 1/16 x 3 3/4	220.0	L-AL	6.33	4 deg. B.T.C.
Ford	3 1/16 x 3 3/4	220.0	L-AL	6.33	4 deg. B.T.C.
Ford	3 1/16 x 3 3/4	220.0	L-AL	6.33	4 deg. B.T.C.
Graham	3 1/4 x 4	265.4	L-AL	6.72	3 deg. B.T.C.
Oldsmobile	3 x 4 1/4	240.3	L-C.I.	5.7	4 deg. B.T.C.
Packard	3 3/16 x 5	320.0	L-C.I.	6.0	11 deg. B.T.C.
Packard	3 3/16 x 5	320.0	L-C.I.	6.58	7 deg. B.T.C.
Plymouth	3 1/8 x 4 3/8	201.3	L-C.I.	5.8	9 deg. B.T.C.
Plymouth	3 1/8 x 4 3/8	201.3	L-AL	6.5	6 deg. B.T.C.
Plymouth	3 1/8 x 4 3/8	201.3	L-C.I.	5.8	3 deg. A.T.C.
Plymouth	3 1/8 x 4 3/8	201.3	L-C.I.	5.8	3 deg. A.T.C.
Pontiac	3 3/16 x 3 1/2	223.4	L-C.I.	6.2	7 deg. B.T.C.
Studebaker	3 1/4 x 4 1/8	205.3	L-AL	6.3	T.D.C.
Terraplane	3 x 5	212.1	L-C.I.	5.8	12 deg. B.T.C.
Terraplane	3 x 5	212.1	L-AL	6.3	12 deg. B.T.C.
Terraplane	3 x 5	212.1	L-AL	7.0	12 deg. B.T.C.

the road-testing program. A description of this hill is given in the papers covering the 1932 project[3].

Road-Test Procedure

As provided in the program, the C. F. R. Road-Test Method for Determining Relative Antiknock Value of Motor Fuels[4], adopted by the Cooperative Fuel Research Committee in 1932, was used as the basic procedure in conducting the tests.

The test conditions imposed in the C. F. R. road-test method are slow acceleration or slow deceleration, in high gear with wide-open throttle, such slow rate of acceleration or deceleration to be maintained by highway grade, by brakes or by towing another vehicle on a level road. The results obtained on runs in which slow acceleration was maintained by the highway grade were the only road ratings obtained at Uniontown by the approved C. F. R. method and are hence referred to hereafter as the C. F. R. Road Ratings.

The identity of the branded fuels was concealed throughout the tests. The identity of the non-branded fuels was revealed at the completion of specific portions of the program, but the fuels were re-coded for the remainder of the tests. The test fuels were bracketed between increments of 10-per-cent blends of A-3 and C-8.

The personnel assigned to road work consisted of groups of two observers and a driver, except in the case of two coupés, in which only one observer did the rating. When the two observers in a given car had obtained ratings in substantial agreement on all fuels, a second group was sent out to check the ratings of the first group. If the second group did not check the results of the first group within 10-per-cent C-8, subsequent groups were sent out until agreement was obtained. In carrying out the provisions of the road-test procedure certain expedients were adopted to secure the maximum number of ratings. An explanation of these follows.

(1) *Spark Advance.*—All fuels were run in all cars with the spark adjusted according to the manufacturer's basic setting, which is the preferred practice of the C. F. R. road-test method. To obtain ratings on the several fuels which did not knock with the basic spark setting, the spark was advanced. It was felt that this was justified, because in many cases the manufacturer's basic setting was later than that required for maximum power; also, several cars were supplied with octane selectors, which enabled the driver readily to adjust this setting for maximum performance with the fuel in use. Thus these cars, when in operation, would not necessarily be operated at the manufacturer's basic setting.

(2) *Extrapolation.*—Fuels Nos. 3, 11 and 12 did not knock in several of the cars unless the spark was advanced beyond the position for maximum power. To obtain a more nearly representative rating on these fuels, it was deemed desirable to bring these fuels within the knocking range of the cars rather than advance the spark beyond the position for maximum power. This was accomplished by blending the fuels with Fuel No. 14 to lower their octane numbers. Realizing the danger of changing the character of the original fuel, the minimum of diluent was used. The blends used contained 7, 14, and 25 per cent of diluent. At least two blends were rated and used in conjunction with the rating of Fuel No. 14 to obtain a curve, which was extrapolated to give the rating of the fuel. Ratings of this type were obtained on cars Nos. 2, 4, 8 and 9, on Fuel No. 12; Cars Nos. 2 and 11, on Fuel No. 11; and Cars Nos. 2, 4 and 11, on Fuel No. 3.

Supplementary Test Methods

In addition to the C. F. R. procedure described above, other methods of rating fuels on the road were investigated. These methods were: level road, cross-country runs, and hill tests with the detonation meter.

The object of the level-road and cross-country runs was to obtain some indication as to whether the C. F. R. road-test method represented conditions approaching in severity those of ordinary car usage, and whether such degree of severity would appreciably affect road ratings of fuels. The level-road runs represented, of course, the conditions of lesser severity, and the cross-country runs those of greater severity.

(1) *Level-Road Ratings.*—A program was laid out to obtain a comparison between ratings made on the hill by the C. F. R. method and on a level road using the method described below. In this work only the non-branded fuels and the following cars were used:

Cadillac	Packard
Chevrolet	Plymouth
Chrysler	Pontiac
Dodge	Terraplane
Ford	

In these tests mixture ratio and spark settings were also maintained at manufacturers' recommendations, except when necessary to advance the spark as was done in the hill tests.

Because of the difficulty encountered in obtaining consistent agreement in the first part of the level-road work, it was found advisable to obtain a measure of the accuracy of this particular work. This was accomplished by the so-called "blind" tests in which the reference fuels were coded and the test fuels were recoded, and the observers ran the tests wholly without knowledge of the identity of the fuels being used.

The location chosen was a section of approximately level road ¾ mile long, having slight grades at either end which were used for turning and changing fuels. The procedure followed was to run the cars at 10 m.p.h., then to accelerate with wide-open throttle through the speed range of the car. Because of the rapid acceleration, only the maximum knock

[3] See *Proceedings of the American Petroleum Institute*, 13 (III) 141, 1932. See also S.A.E. JOURNAL, March, 1933, p. 108.
[4] See S.A.E. JOURNAL, March, 1933, p. 120.

intensity was observed. The C. F. R. road-test method, it will be recalled, provides for slow acceleration and for rating to be made of knock intensity at speed intervals of 5 m.p.h. in the range between 15 and 50 m.p.h. The speeds at which knocking started and died out were noted as well as that for maximum knock. The maximum knock intensity of the test fuel was then compared with maximum knock intensity of blends of reference fuels A-3 and C-8 in proportions varying in increments of 10 per cent.

(2) *Cross-Country Ratings.*—To obtain data for directly comparing some of the C. F. R. road ratings with ratings secured at higher road speeds, three groups were sent out to make ratings under the conditions of hard cross-country driving. The following cars and fuels were used: Cars Nos. 6, 8 and 15, and Fuels Nos. 5, 7 and 12. An attempt was made to drive the cars during tests in such manner as to secure the most severe conditions that might reasonably be encountered in service, in the hope of producing maximum combustion-chamber temperatures. The driving procedure used was as follows:

(*a*) Full-throttle driving at 60 to 70 m.p.h.
(*b*) Decreasing the car speed to 40 m.p.h. with the brake, with the throttle closed
(*c*) Opening the throttle wide
(*d*) Allowing car to accelerate to 60 to 70 m.p.h., if possible.

This procedure was duplicated about 8 to 10 times on both hill and level stretches of the road. To obtain the low-speed knock intensity, the same procedure was used, except that the car speed was reduced to 10 m.p.h.

(3) *Detonation Meter Ratings.*—Additional ratings were made on the hill, using a "detonation meter" supplied by the Electrical Research Products, Inc. The object of this work was: (*a*) to compare ratings obtained by this electrical means with those obtained by the aural method; and (*b*) to familiarize the group with the instrument. The following fuel-car combinations were used:

Car No. 11′ . . Fuels No. 5, 12, 3, 11, 12′
Car No. 8 . . . Fuels No. 2, 11, 11′, 11″, 11‴, 12, 12′, 12″
Car No. 12 . . . Fuel No. 9
Car No. 6 . . . Fuel No. 6
Car No. 5 . . . Fuels No. 3, 6, 7, 10, 12

In the majority of cases, ratings were made simultaneously by both methods.

Special Reference Fuels

Since Reference Fuel C-8 (see Table 2) is more volatile than the conventional fuels, the effect on detonation ratings of this difference in distillation characteristic was investigated. Fuel b-9, a California straight-run naphtha, having a conventional distillation and an octane-number rating of 72, was used for this purpose.

Table 4—C. F. R. Road Ratings

		Uniontown Code Branded Fuels							Uniontown Code Non-Branded Fuels								
		1	3	4	6	13	14	16	12	5	10	8	2	9	11	7	15
Car Numbers									C.F.R. Code b-1	b-2	b-3	b-4	b-5	b-6	b-7	b-8	b-9
	1	76	98	44	68	73	15	82	94	70	66	66	85	73	95	71	87
	2	78	103	47	72	71	20	79	98	69	69	61	89	78	100	87	87
	3	78	98	45	73	73	19	79	90	68	72	63	86	76	92	89	88
	4	77	105	51	70	78	20	88	101	70	79	57	97	83	..	..	95
	5	80	98	48	75	70	17	80	97	75	79	68	93	81	97	97	88
	6	78	100	45	70	67	..	73	73	68	72	63	94	74	97	99	90
	7	67	..	55	67	69	..	78	64	67	57	56	75	72	..	76	..
	7′	68	99	48	69	69	..	68	72	65	65	58	81	71	86	72	89
Average	7 and 7′	68	99	52	68	69	..	73	68	66	61	57	78	72	86	74	89
	8	68	..	47	73	70	..	77	73	64	62	54	..	77	..	75	..
	9	76	..	50	70	70	21	77	85	66	65	61	..	73	..	..	..
	10	73	95	47	70	68	..	70	93	69	69	60	87	73	93	79	89
	11	73	..	43	73	73	21	77	..	70	74	63	78	78	..	79	82
	11′	76	106	43	76	..	..	77	79	77	70	68	82	78	102	68	83
Average	11 and 11′	75	106	43	75	73	21	77	79	74	72	66	80	78	102	74	83
	12	69	..	49	72	64	..	72	..	65	63	57	80	72	90	77	86
	13	..	..	44	..	..	..	..	..	..	..	..	..	..	..	..	..
	13′	73	..	40	68	68	..	76	..	66	68	60	79	75	..	76	83
	13″	..	99	..	..	..	..	..	90	..	..	..	82	..	97	..	87
Average	13, 13′, and 13″	73	99	42	68	68	..	76	90	66	68	60	81	75	97	76	85
	14	..	..	48	..	..	14	..	..	..	..	..	..	..	..	..	..
	15	76	101	41	72	70	..	78	92	67	69	63	87	77	93	79	87
	16	73	..	48	73	77	9	..	..	70	..	61	..	..	..	76	..
	17	77	97	..	72	68	..	77	..	66	75	67	90	76	95	..	87
	18	73	86	47	..	..	..	72	..	56	65	55	90	70	..	..	..
	18′	..	90	..	64	61	..	70	69	..	..	..	80	63	90	79	..
Average	18 and 18′	73	88	47	64	61	..	71	69	56	65	55	85	67	90	79	..
	19	68	90	39	71	66	..	70	65	54	53	50	73	71	85	65	84
Number of Car Ratings		18	14	18	18	18	9	17	15	18	17	18	15	17	14	15	14
C.F.R. Hill	Average Per Cent C-8	74	98	46	71	70	17	76	84	67	68	61	86	75	94	80	87
	Equivalent Octane No.	68.9	76.5	59.5	67.9	67.6	49.4	69.5	72.1	66.6	66.8	64.5	72.7	69.2	75.1	70.8	73.0
	Motor, Octane No.	68.2	76.2	59.8	69.5	68.7	51.3	70.0	70.8	65.9	65.9	64.1	70.6	69.3	74.0	68.1	72.0
	Research, Octane No.	71.0	79.9	59.4	71.3	70.7	51.0	71.6	79.9	76.3	70.2	67.6	74.9	71.7	78.8	72.5	73.0

Prime = High-compression head. Low-compression and high-compression ratings averaged to give car rating.

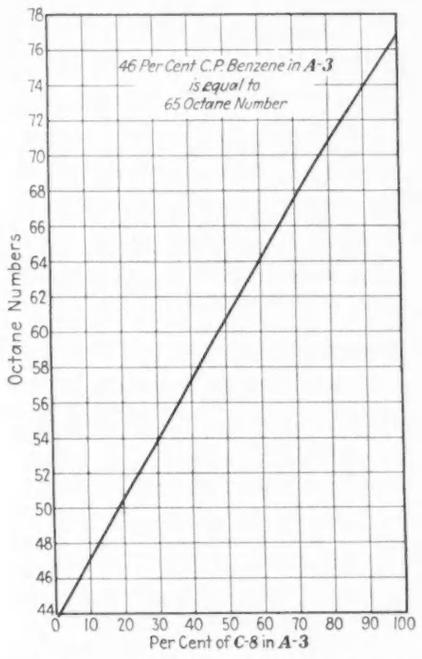


Fig. 1—Calibration Curve of Blends of Standard Reference Fuels A-3 and C-8 in Terms of Octane Number. (A.S.T.M. Designation D-357-33T)

A direct comparison between the knocking characteristic of Fuel b-9, the other test fuels, and blends of Reference Fuels C-8 and A-3 was obtained in all but five cars. To obtain this comparison in the five cars in which Fuel b-9 did not knock, Fuel b-9 was blended with A-3 in proportions of 40 and 15 per cent of the latter (fuel designation R-1 and fuel designation R-2, respectively, see Table 8). The results obtained with these blends were then compared directly with those of Reference Fuels and Test Fuels b-3 and b-4; and a blend of 25-per cent benzol, 25-per cent C-8, and 50-per cent A-3 (fuel designation R-3, see Table 8). This last blend was run at the request of the representatives of the Institution of Petroleum Technologists.

Results

(1) *Laboratory Ratings.*—The laboratory ratings were obtained by the present C. F. R. motor method (A.S.T.M. designation D-357-33T). Ratings were made immediately preceding the road work by the C. F. R. Monthly Exchange Group, consisting of 19 laboratories. The average value for each fuel was then ascertained.

Immediately following the road tests, a second set of samples of the original fuels used at Uniontown was shipped from a central laboratory to the exchange group, with the exception of one laboratory which was omitted and two which were added to the list. The average values from these tests were then ascertained, and the mean of these two separate determinations used as the octane rating of the fuel. These ratings are shown in Table 4. Seven of the laboratories also rated are the first set of samples by the research method, the average of the results obtained being given in Table 4.

(2) *C. F. R. Road Rating.*—The C. F. R. road ratings of fuels are shown in Table 4. The following method was used in obtaining the ratings:

(*A*) Ratings were obtained by at least two groups, as previously described.

(*B*) Two group ratings were then averaged to obtain a car rating, provided they checked within 10 per cent of C-8 in A-3. (Fig. 1 presents calibration curve of blends of standard Reference Fuels A-3 and C-8 in terms of octane numbers as determined by the C.F.R. Motor Method (A.S.T.M. Designation D-357-33T). When those two group ratings did not check, additional groups were sent out in an attempt to reach agreement. In six cases ratings outside the 10 per cent of C-8 range were used in computing the average provided that three or more ratings were obtained which, although differing by 5 to 10 per cent of C-8 among themselves, were all within a range of 15 per cent of C-8. If no satisfactory agreement was reached, the ratings were discarded. Forty-five group-ratings, out of a total of 653 (less than 7 per cent), were discarded.

This group of 45 discarded ratings was made as follows:

Twenty-five ratings did not check within the 10 per cent C-8 spread agreed upon by the Uniontown group.

Thirteen ratings were obtained, but subsequent groups were unable to check these values due to changes in the octane requirements of the cars brought about by weather conditions. An illustration of this is given under octane requirements of cars.

Six ratings were obtained in Car No. 12 with abnormal spark settings which were not considered representative of normal road operation and, consequently, discarded even though they were not out of line with ratings obtained with normal spark settings.

One rating was discarded due to question of its validity by the observers.

Exceptions to this procedure were made in cases where there were three cars of the same make. In these cases, if two of the three cars gave ratings which checked, and one group rating had been obtained on the third car, which also checked the other two car ratings, that rating was considered as the rating of the third car.

(*C*) The car ratings listed in Table 4 were averaged to give the road rating of the fuel. When more than one cylinder head was used on any car, the ratings obtained with the various heads were still considered as having been made with a single car, regardless of whether they were obtained while using one, two, or three heads. This accounts for some of the blanks in the table.

Since it was not practicable to rate all fuels in all cars, the group voted that a minimum of 15 car ratings would constitute a fuel rating. Because of the low octane number of Fuel No. 14 and the low octane requirements of Cars Nos. 14 and 16, it was further decided not to attempt to obtain ratings in the majority of cases involving the use of this fuel and these cars. The fact that the two cars mentioned were included in some of the fuel averages does not materially alter these values; for, by excluding Cars Nos. 14 and 16, a maximum change of +2 per cent C-8 in A-3 would occur with Fuel No. 14, while the other averages would be changed by less than 0.5 per cent C-8.

These three factors, that is, optional heads, the partial elimination of Fuel No. 14, and Cars Nos. 14 and 16, account for 84 per cent of the blanks in the table. The ratings obtained at settings other than the manufacturer's basic setting were segregated, and some fuels were run at both settings to determine the effect of spark advance on the ratings. A comparison of these results (Fig. 2) shows that, within the accuracy of the tests, there is no significant difference between the two ratings. In no case, with the single exception of one make of car, were ratings used which were obtained with spark setting beyond the position for maximum power.

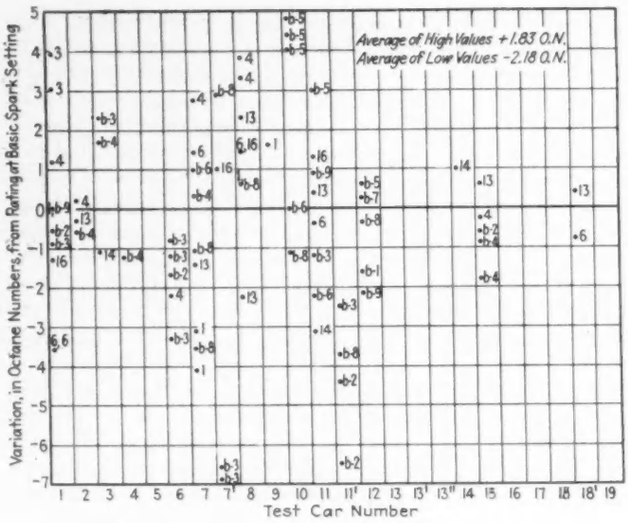

Average of High Values +1.83 O.N.
Average of Low Values -2.18 O.N.
Variation, in Octane Numbers, from Rating at Basic Spark Setting
Test Car Number

Fig. 2—Effect of Spark Timing on Road Knock Ratings
Variation, in octane numbers, from rating at basic spark setting

(3) *Level-Road Ratings.*—Table 5 shows the results of the level-road tests. In these tests the car ratings were obtained from the group ratings as described in the C. F. R. road tests; these were averaged to give the level-road fuel-ratings.

A comparison of the results of the level-road tests with those obtained on the hill, as shown in Table 4, shows that there is no significant difference between these ratings; the maximum difference being 4 per cent of C-8 in A-3 in the case of Fuel b-1, which is equivalent to 1.3 octane numbers. Therefore, it was unnecessary to complete this series of tests for all fuels in all cars. As previously mentioned, the majority of these tests was run "blind."

The outcome of these "blind" tests showed very definitely that it is possible to obtain good results if the tests are run expertly, under the most favorable conditions, and accurately observed. Thus, out of a total of approximately 165 runs on reference fuels, used either in bracketing the test fuels or run against each other for purposes of determining the accuracy of the observer, there were only seven cases in which the order of the rating of the fuels was reversed. Of these seven reversals, three occurred with such heavy knocking intensities that the observers questioned the validity of their values.

The balance of the results, when plotted, showed spreads that were comparable with those obtained on the hill when the reference fuels were known. An important conclusion to be drawn from this piece of work is that, for greatest accuracy, heavy knocking intensities should be avoided. Since this "blind" method proved so satisfactory, suitable changes have been made in the C. F. R. Road-Test Method to provide definitely for such a procedure. (See Appendix).

(4) *Cross-Country Ratings.*—Table 6 shows a comparison of ratings made during cross-country driving with the C.F.R. road ratings and those made on the level. Although only a limited amount of such data was obtained, it indicates that the cross-country tests were more severe than those run by the other methods.

(5) *Detonation-Meter Ratings.*—Table 7 shows the average variation of the detonation-meter ratings from the average hill ratings. The limited amount of work done with the detonation meter was not sufficient to be conclusive. It did indicate, however, that the use of an electric meter was promising enough to merit further investigation and development; it is, therefore, being studied further by the Committee.

(6) *Special Reference Fuels.*—The ratings shown for Fuel b-9 in Table 4 show no significant variations from car to car, nor between car and laboratory ratings. Therefore, either Fuel b-9 or Fuel C-8 might equally well have been used as reference fuel. Since these two fuels differed markedly in volatility, it follows that the effect of reference-fuel volatility on ratings is negligible insofar as these particular reference fuels are concerned. A summary of the results obtained, using other special reference fuels, is shown in Table 8.

Correlation

The first objective of the 1934 detonation road tests was to check the validity of correlation between road knock ratings and laboratory knock ratings by the C.F.R. motor method (A.S.T.M. designation D 357-33T).

Table 5—Level-Road Ratings

		Non-Branded Fuels								
Uniontown Code		12	5	10	8	2	9	11	7	15
C. F. R. Code		b–1	b–2	b–3	b–4	b–5	b–6	b–7	b–8	b–9
	1	..	..	..	..	..	..	96	83	..
	3	99	71	74	65	88	72	95	88	87
	4	93	74	76	63	95	92	98	104	94
	8	N.K.[a]	N.K.	N.K.	N.K.	N.K.	N.K.	N.K.	N.K.	N.K.
	9	88	71	68	63	89	76	..	N.K.	86
	10	100	80	..	71	94	84	100	..	94
	11′	90	..	54	54	93	81	..	68	89
	13″	98	70	68	..	83	66	94	80	86
	15	..	65	68	53	80	76	..	81	84
	18′	71	58	59	56	75	67	91	..	90
	19	66	58	58	58	71	65	83	65	86
Road	Average Per Cent C-8	88	68	66	60	85	75	94	81	88
Road	No. of Ratings	8	8	9	9	9	9	7	7	9
Road	Equivalent Octane No.	73.4	66.9	66.2	64.2	72.4	69.2	75.1	71.1	73.4
C. F. R.	Motor, Per Cent C-8	80	65	65	60	79	75	90	71	84
C. F. R.	Research, Per Cent C-8	112	78	78	70	94	84	109	86	87
C. F. R.	Motor, Octane No.	70.8	65.9	65.9	64.1	70.6	69.3	74.0	68.1	72.0
C. F. R.	Research Octane No.	79.9	70.3	70.2	67.6	74.9	71.7	78.8	72.5	73.1

[a] N.K. = No knock.

Table 6—Comparison of Cross-Country, Hill, and Level-Road Ratings (Values in Per Cent of C-8 in A-3)

	Car No. 15			Car No. 8			Car No. 6		
	Cross-Country, Per Cent	C. F. R., Per Cent	Level-Road, Per Cent	Cross-Country, Per Cent	C. F. R., Per Cent	Level-Road, Per Cent	Cross-Country, Per Cent	C. F. R., Per Cent	Level Road, Per Cent
Fuel No. 5	67	67	65	58	64	71	65	68	74
Fuel No. 7	73	79	81	70	75	N.R.	95	99	104
Fuel No. 12	90	92	N.R.	55	73	..	85	90[a]	..

[a]A rating made on the hill in the same car gave a rating of 90 per cent to equal Fuel No. 12.

Table 4 gives a comparison of C.F.R. road ratings of the test fuels with the laboratory ratings obtained by the A.S.T.M. and research methods. The maximum variations from the A.S.T.M. method, which occurred in the cases of Fuels Nos. b-8 and 14, are +2.7 and —1.9 octane numbers, respectively; and the algebraic average variation for all fuels is +0.36 octane number. The degree of correlation between ratings by the A.S.T.M. method and the C.F.R. road ratings is shown in Fig. 3. In this it will be noted that the 45-deg. line illustrates perfect correlation. The points are the average road ratings for each test fuel as given in Table 4, and the height of the vertical rectangles represents the average spread of the road ratings. These spreads illustrate the difficulty involved in attempting to develop a laboratory method which will give better correlation until these spreads can be reduced by a more closely indicative method of road test or by bringing engines and fuels to a higher degree of uniformity in mutual detonation behavior. Analysis of the data mathematically or graphically, as in Fig. 3, indicates that the correlation between the present A.S.T.M. method and the Uniontown road-test data is within the limits of experimental error of the technique employed. However, it is apparent from the data that the precision and reproducibility of both the road and laboratory method are not as good as could be desired, and it is not likely that better correlation than has been found in these tests can be achieved until improvements in precision have been developed. Active work along these lines is in progress.

Engine Severity Factor

(1) *Deviation of Individual Ratings from Average.*—The second objective of the tests was to indicate promising paths of research directed toward better mutual adaptation of fuels and engines. This required further analysis of the data, carried from the realm of averages to that of individual fuel and engine performance.

The results of the Uniontown tests show two outstanding facts: first, that good agreement or correlation between the A.S.T.M. and the C.F.R. road ratings was obtained when average ratings were used; and second, that in a few cases wide deviations were found when certain individual results were compared.

Experience indicates that individual road ratings are reproducible within about 10 per cent C-8 if they are made *under identical conditions,* with the same car. It thus seems that the average of at least two ratings in each of 15 or more cars should be reproducible within close limits and should represent the road rating of a fuel within less than ½ octane number. However, careful analysis of the data indicates that the average road ratings are not reproducible quantities within plus or minus one to two octane numbers. For example, the straight-run Gasoline b-9 had an average road rating one octane number above the A.S.T.M. rating, and Fuel 14, obviously one of the two third-grade gasolines and therefore also a straight-run fuel, was 1.9 octane numbers below the A.S.T.M. rating. From knowledge of their composition and

Table 7—Average Variation of Detonation-Meter Readings from the Average C. F. R. Road Ratings [a]

Car No.		Per Cent C-8
8	Rated Fuels 3, 11, 12 as well as primes giving average variation	−5
12	Rated Fuel 9 giving average variation	0
6	Rated Fuel 12 giving average variation	+7
5	Rated Fuels 3, 6, 7, 10, 12 giving average variation	+1
11′	Rated Fuels 3, 5, 7, 11, 12 giving average variation	−4

[a]Overall variation (all cars, all fuels rated) —2 per cent C-8 from C.F.R. Road Rating with natural car.

Table 8—Reference-Fuel Ratings

Fuel Designation		Per Cent C-8 in A-3				
		R-1	R-2	R-3	b-3	b-4
Car No.	5	54	..	..	..	67
	9	55	..	..	..	..
	10	51	72	66	71	57
	15	49	..	61	..	59
	18′	..	73	67	58	52

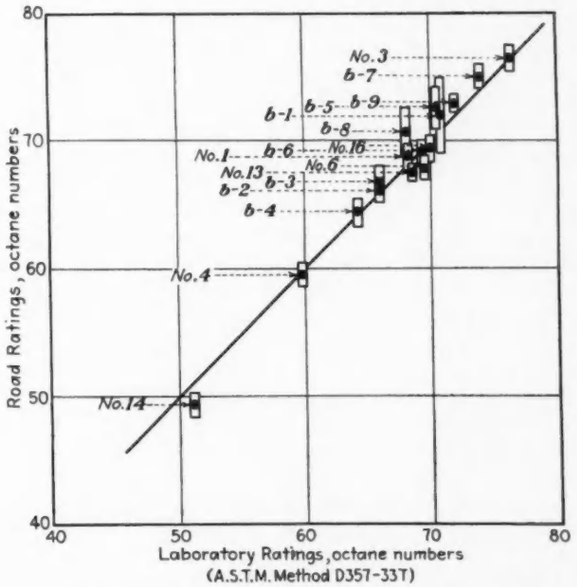


Fig. 3—Correlation between Road and Laboratory Ratings

Table 9—Deviations from Average Fuel Ratings[a]

		Branded Fuels							Non-Branded Fuels									Average	Max. Plus Deviation	Max. Minus Deviation
Uniontown Code		1	3	4	6	13	14	16	12	5	10	8	2	9	11	7	15			
C. R. F. Code									b-1	b-2	b-3	b-4	b-5	b-6	b-7	b-8	b-9			
Car Number	1	+2	0	−2	−3	+3	−2	+6	+10	+3	−2	+5	−1	−2	+1	−9	0	+0.6	10	9
	2	+4	+5	+1	+1	+1	+3	+3	+14	+2	+1	0	+3	+3	+6	+7	0	+3.4	14	0
	3	+4	0	−1	+2	+3	+2	+3	+6	+1	+4	+2	0	+1	−2	−9	0	+2.1	9	2
	4	+3	+7	+5	−1	+8	+3	+12	+17	+3	+11	−4	+11	+8	..	..	+8	+6.5	17	4
	5	+6	0	+2	+4	0	0	+4	+13	+8	+11	+7	+7	+6	+3	+17	+1	+5.6	17	0
	6	+4	+2	−1	−1	−3	..	−3	−11	+1	+4	+2	+8	−1	+3	+19	+3	+1.7	19	11
	7	−7	..	+9	−4	−1	..	+2	−20	0	−11	−5	−11	−3	..	−4	..	−3.9	9	20
	7′	−6	+1	+2	−2	−1	..	−8	−12	−2	−3	−3	−5	−4	−8	−8	+2			
	8	−6	..	+1	+2	0	..	+1	−11	−3	−6	−7	..	+2	..	−5	..	−3.0	2	11
	9	+2	..	+4	−1	0	+4	+1	+1	−1	−3	0	..	−2	..	0	..	+0.4	4	3
	10	−1	−3	+1	−1	−2	..	−6	+9	+2	+1	+1	+1	−2	−1	−1	+2	−0.1	9	6
	11	−1	..	−3	+2	+3	+4	+1	..	+3	+6	+2	−8	+3	..	−1	−5	+0.8	10	12
	11′	+2	+8	−3	+5	..	..	+1	−5	+10	+2	+7	−4	+3	+8	−12	−4			
	12	−5	..	+3	+1	−6	..	−4	..	−2	−5	−4	−6	−3	−4	−3	−1	−3.0	3	6
	13	..	..	−2	..	..	..	..	..	..	..	..	..	..	..	..	..			
	13′	−1	..	−6	−3	−2	..	0	..	−1	0	−1	−7	0	..	−4	−4	−1.4	6	7
	13″	..	+1	..	..	..	..	..	+6	..	..	..	−4	..	+3	..	0			
	14	..	..	+2	..	..	−3	..	..	..	..	..	..	..	..	..	..	−0.5	2	3
	15	+2	+3	−5	+1	0	..	+2	+8	0	+1	+2	+1	+2	−1	−1	0	+1.0	8	5
	16	−1	..	+2	+2	+7	−8	..	..	+3	..	0	..	..	..	−4	..	+0.1	7	8
	17	+3	−1	..	+1	−2	..	+1	..	−1	+7	+6	+4	+1	+1	..	0	+1.7	7	2
	18	−1	−10	+1	..	..	..	−4	..	−11	−3	−6	+4	−5	..	..	..	−5.6	4	15
	18′	..	..	..	−7	−9	..	−6	−15	..	..	..	−6	−12	−4	−1	..			
	19	−6	−8	−7	0	−4	..	−6	−19	−13	−15	−11	−13	−4	−9	−15	−3	−8.9	0	19
Average		3.35	3.5	3.0	2.2	2.9	3.2	3.7	11.1	3.5	5.05	3.95	5.5	3.35	3.9	6.7	2.1			
Maximum Spread		13	18	16	12	17	12	20	37	23	26	18	24	20	17	34	13			

[a]Deviations are expressed in per cent of Reference Fuel C-8 in Reference Fuel A-3

because of their insensitivity to operating conditions as evidenced by the relatively small difference between their Research and A.S.T.M. ratings, neither of these gasolines would be expected to deviate from the A.S.T.M. ratings appreciably when rated on the road. Even if only those cars are considered in which both fuels were rated approximately the same variation exists. In this same connection, Fuels 6 and b-6, of nearly identical composition so far as can be judged by available data and of identical laboratory ratings, had average road ratings varying by 1.3 octane numbers.

Further evidence that the average road ratings do not represent the road rating of the fuel to within plus or minus one or two octane numbers lies in the fact that in some cases the average road rating of a fuel in two identical cars varied widely. Extreme examples of this are Cars 4 and 6 of the same make and model which gave ratings on Fuel 12 differing by 28 per cent C-8 and Cars 7 and 9 in which the same fuel differed by 21 per cent C-8.

While the degree by which the C.F.R. road ratings approximate true road ratings of fuels cannot be determined, it is indicated by the fact that Fuel 14, referred to above, gave a road rating which deviated from the A.S.T.M. rating by 1.9 octane numbers. No other fuel except the benzol blend, No. 7 (b-8) deviated more than this amount, and since the average deviation (omitting Fuel No. 7) is only +0.02 octane numbers, the plus deviations approximately equal the minus deviations. Fuel 14 has maximum minus deviation but, from Table 4, Fuel b-5 (2) has a greater deviation, being +2.1. Although the road values obtained only approximately represent the true road ratings, they are the most accurate that can be obtained with the present knowledge of the subject. This is indicated by the fact that the forty odd men who participated in the work unanimously agreed before they knew what the laboratory values were that the road ratings were as representative as they could obtain them. Thus any laboratory procedure cannot be said to give better correlation with road ratings than does the A.S.T.M. method until more exact road ratings are obtained.

Research might well be directed toward ascertaining whether some refinement in method or closer control of test conditions might serve to bring about closer harmony in the ratings of similar fuels. In addition, larger definite and reproducible variations in ratings, apart from experimental error, are apparent. They represent real differences between cars in the rating of any one fuel. This is to be expected from ratings obtained from engines of many totally different designs. Fig. 3 shows the degree of accuracy with which the A.S.T.M. test will predict the average road performance of a fuel in representative cars. However, if individual car ratings of each fuel were shown on this figure, the points would be distributed within a band 7 to 8 octane numbers wide and on both sides of the 45-deg. line.

An examination of Table 9 shows that in the case of the branded fuels the greatest of the average deviations from the average fuel rating is 3.7 per cent C-8, while the maximum spread for any given fuel, which maximum occurred with Fuel No. 16, is 20 per cent C-8. With the non-branded fuels, the average deviation is only slightly greater, with the exception of Fuels Nos. 12 and 7, which showed average deviations of 11.1 and 6.7 per cent C-8 respectively, and a maximum spread of 37 per cent C-8 and 34 per cent C-8, respectively. The chart shown in Fig. 4 shows in graphical form the data given in Table 9.

The solution of the correlation problem requires the setting up of specified engine conditions which will produce results equivalent to reasonably representative road results. The fact that the deviations when averaged do approach the average A.S.T.M. rating to the extent shown in Fig. 3 is a measure

of the validity of the laboratory method. It is obvious that any attempt to make this method more representative of the behavior of engines at one end of the scale would impair its value as a criterion for fuel behavior in engines at the other end of the scale.

Consideration of these deviations leads to the conclusion that two avenues are open for the better adaptation of fuels and engines: first, the immediate expedient of using in each individual current engine the current fuels best adapted to it; and second, to discover what factors of fuel composition or engine design may be changed to secure better adaptability in this respect without entailing other and perhaps more deleterious consequences in other respects.

(2) *Concept of Engine Severity Factor.*—These tests again brought out, first, that different cars may rate the same fuel differently because of variations of some unknown factors; second, that fuels differ in their susceptibility to these factors in regard to their knock rating.

The susceptibility of a fuel can be determined by noting the effect of some given change in engine conditions on the knock intensity of the fuel as compared to the effect of the same change on the knock intensity of a reference fuel. The difference between the C.F.R. Research rating and the A.S.T.M. rating is such a determination and is called the Fuel Sensitivity.

[5] See S.A.E. JOURNAL, May, 1933, p. 187.

Some cars rated the fuel consistently higher, others consistently lower, than the A.S.T.M. rating. This tendency can be expressed by a ratio called the Severity Factor. The ratio of Research Road-Rating to the fuel sensitivity gives the relative severity of the car compared to the severity of the A.S.T.M. method. Thus, if the car rating equals the A.S.T.M. rating, this ratio will be one, indicating that the car subjects the fuel to conditions of the same severity as does the A.S.T.M. method relative, of course, to the reference fuels. If the car rating is half way between the Research and A.S.T.M. rating, the ratio will be 1/2, indicating that the car is less severe than is the A.S.T.M. engine, and if the ratio is greater than one the car is more severe. This ratio is called the Severity Factor and was first introduced by Donald Brooks[5] in a discussion of the 1932 work.

The numerical value of the "severity factor" is an expression for this tendency of a car to rate fuels high or low, using as a basis of comparison the Research and Motor or A.S.T.M. ratings. The term relates to cars and conditions under which they are operated in a manner complementary to that in which the sensitivity factor is applied to fuels. It is:

$$\text{Severity Factor} = \frac{\text{Research Method Rating—Road Rating}}{\text{Research Method Rating—A.S.T.M. Rating}}$$

It will be noted that the denominator of this equation is the sensitivity of the fuel as defined above and the numerator is the difference between the Research and Road ratings.

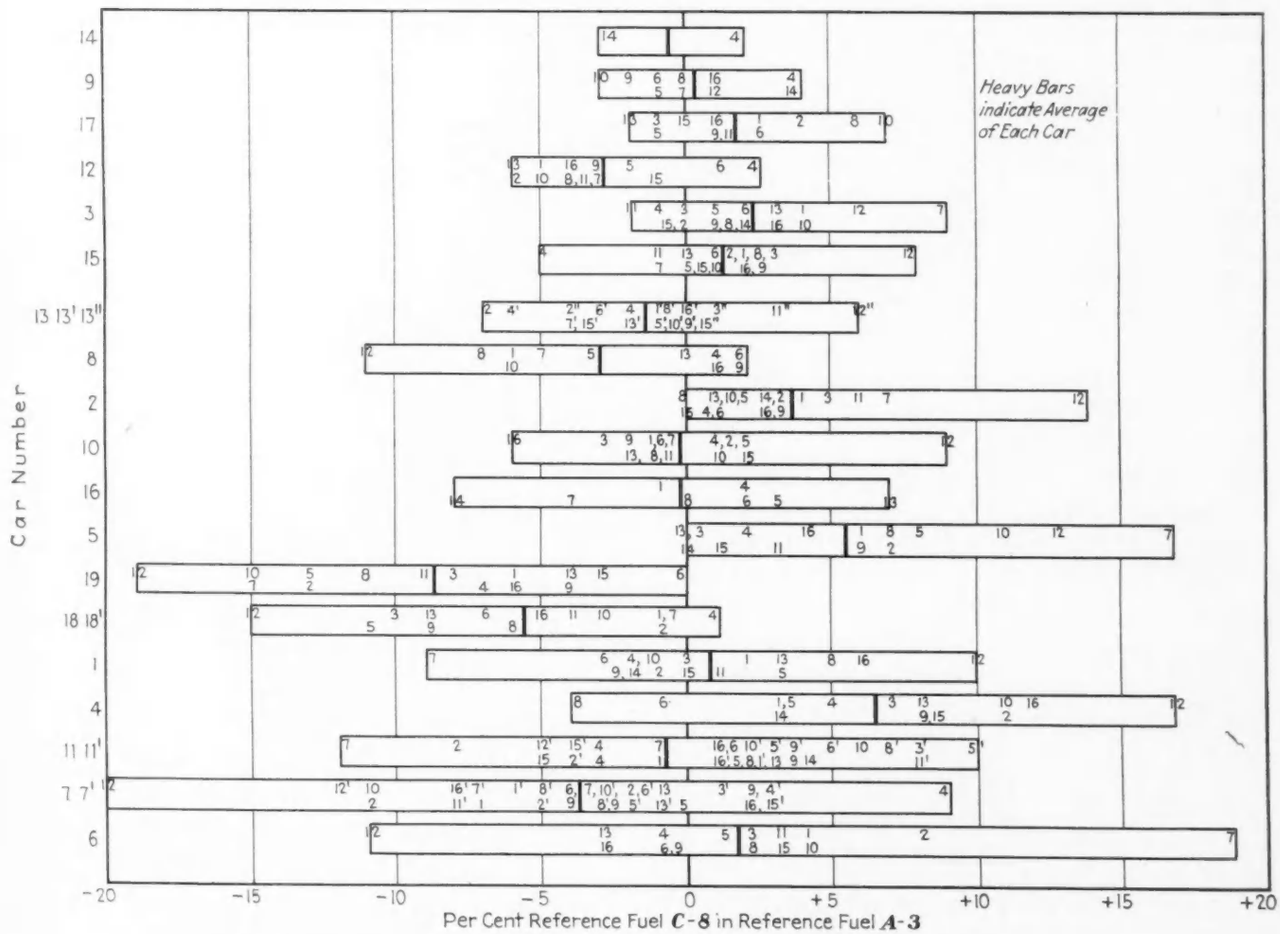


Fig. 4—Deviation of Ratings of Each Fuel in Each Car from the Average Fuel Ratings
The heavy bars indicate the average of each car

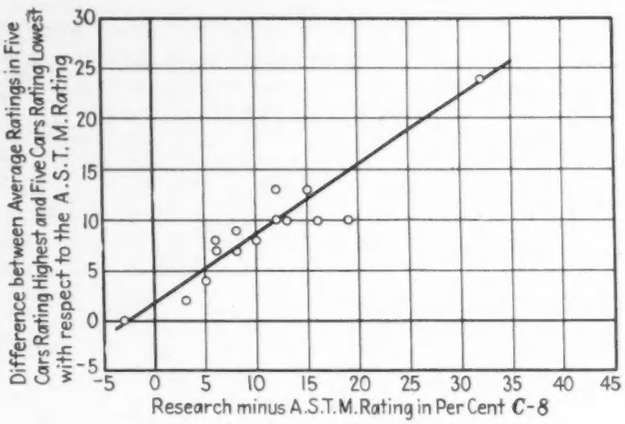

Difference between Average Ratings in Five Cars Rating Highest and Five Cars Rating Lowest with respect to the A.S.T.M. Rating
Research minus A.S.T.M. Rating in Per Cent C-8

Fig. 5—Comparison of Fuel Sensitivity Determined from Road Tests with Sensitivity Determined from Research and A.S.T.M. Ratings

The severity factor as defined above is a ratio and is accordingly dimensionless; it would, therefore, apply to any system of reference fuels, that is, to octane numbers, to per cent of C-8, or to some other reference fuels.

(3) *Application of the Severity Factor.*—The severity factors, when applied to individual ratings in a car, are not constant or consistent, which may be due to changes in some operating condition, because of experimental error or because fuels vary in the degree of their susceptibility to different engine factors. However, when treated statistically, the severity factor indicates that 1934 cars have not changed appreciably in their severity on knock ratings when compared to those of 1932, for the average severity factor of the cars used in the 1932 tests was 0.93 and that of the cars used in 1934 was 0.91.

The severity factor, if it were quantitative and consistent, might be useful in connection with the development of a technique for the improvement of engines with respect to those characteristics which determine the magnitude of the severity factor; or, in other words, the tendency of certain engines to rate sensitive fuels above or below the A.S.T.M. rating.

As another application of the severity factor, it might be used in determining the suitability of any fuel for a given car. For example, given a fuel of 75 octane number and a sensitivity of 10, to be used in a car having a severity factor of 1.5, and an octane requirement of 72; required to determine whether this fuel will knock:

$$\text{Severity Factor} = \frac{\text{Research Rating—Road Rating}}{\text{Research Rating—A.S.T.M. Rating}}$$

$$1.5 = \frac{85\text{—Road Rating}}{10}$$

$$\text{Road Rating} = 70$$

Since the octane requirement of the car is 72, and the road rating of the fuel is 70, the car will knock on the fuel in question.

The severity factor would be most useful if, in the case of a given car, it were constant for all fuels; but it might still be useful if it varied in some consistent manner with certain types of fuel, for example. Computations of severity factors for the cars used at Uniontown from the data taken there do not give a value which is a constant for all fuels in a given car although the average value for the severity factor can be computed with an estimated precision of ±0.1 of a ratio. The average deviation among calculated severity factors for different fuels in a given car is about ±0.4 of a ratio, which is about equal to the deviation to be expected if the probable error of a road rating is of the order of 5 per cent of C-8 and the average sensitivity of the fuels 10 per cent of C-8. This indicates that some variations in severity factors computed for different fuels in the same car can be accounted for by experimental error in road ratings.

Table 10—Comparison of Surveys of Severity Factors of Automobiles

Survey	Number of Cars	Number of Fuels	Total Fuel Sensitivity	Total Road Depreciation	Severity Factor
Uniontown, 1932	15	15	1957	1814	0.93
Uniontown, 1934	19	16	2531	2310	0.91

Certain cautions concerning the use of the severity factor seem to be indicated. Calculations of severity factors from individual ratings which are subject to as much as 5 or 10 per cent of C-8 in experimental error are of doubtful value individually; but, statistically, a large number of such values may have some significance and may be of some value in the study of fuel-car combinations. Since the severity factor is a ratio of difference, moreover, small errors will cause a large percentage of variation in it. It must be considered also that the significance of the ratio grows less as the fuel sensitivity is decreased, until the errors in the ratings become many times greater than the difference in ratings that is being measured.

It was suggested above that the severity factor for a given car might be useful if it varied in some consistent manner, with certain types of fuel, for example.

The severity factor, if it is to be a constant for a given car, precludes the possibility of different fuels having different relative knock susceptibilities to different engine variables. However, the Uniontown data, when analyzed in such a way as to eliminate the disturbing influences of experimental error, indicate that the fuels which appear most sensitive with respect to the road-test reference-fuels as evidenced by the difference between the Research and A.S.T.M. ratings are also the fuels that are most sensitive to variations in road ratings. On the road, fuels generally rated higher or lower than the A.S.T.M. ratings according to their respective sensitivities and according to the severity factors of the cars in which they were rated. For example, the accompanying chart of Fig. 5 shows the correlation between sensitivity as indicated by the difference between the Research and A.S.T.M. ratings and sensitivity as measured by the difference between the average ratings in the five cars having the lowest severity factors and

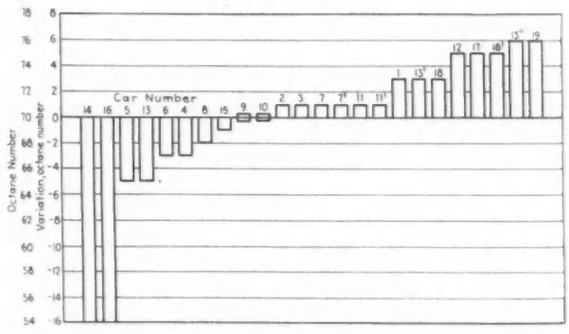


Fig. 6—Octane-Number Requirement of Each Car Showing Deviations from 70.0 Octane Number

ratings in the five cars having the highest severity factors. The intermediate cars were omitted because of so much overlapping in the ratings, believed to be accounted for by experimental error, although inclusion of all cars does not change the picture appreciably except that Fuel b-1 is a little off the line due to one or two doubtful ratings on it.

Factors Affecting Fuel-Engine Relationships

(1) *Factors Indicated by Uniontown Tests.*—Although there is some basis for the concept of severity in connection with the naming of the severity factor if conventional reference fuels and engine conditions are taken as a base line, the severity factor is in reality merely a measure of the departure of the car rating from the A.S.T.M. rating. It is indicative of the difference between the resultant engine conditions under which knock measurements may be made in different engines. The severity factor is a measure of the divergence of a particular car from the average, assuming the A.S.T.M. rating to be equivalent to the average.

Still remaining are the questions as to what constitutes the difference between the engines during knock ratings and what factors contribute to the total differences in the way individual engines handle individual fuels. Further research must be directed toward establishing in a precise manner the

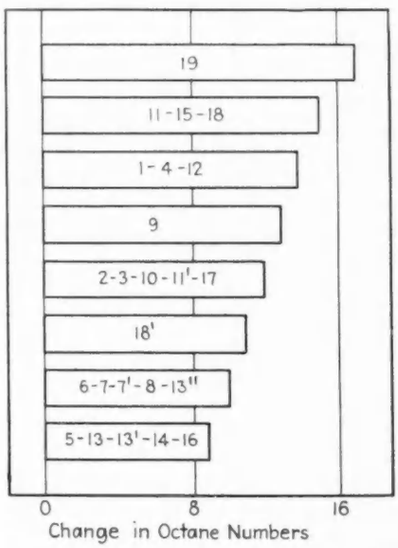


Fig. 7—Change of Knock Intensity with Change in Octane Number of Fuel

The horizontal length of the bars represents the change in octane numbers of the fuels required to change the knock from trace to heavy knock intensity. The figures in the bars represent test-car numbers.

influence of the various factors which may be significant from the viewpoint of severity. Some of these factors, as suggested by experience and by analysis of the Uniontown results, are the following: the octane number requirement of the car, the shape of the knock-intensity-speed curve, the car speed at which the maximum knock occurs, the intensity of knock at which ratings are made, the magnitude of the experimental error in making individual determinations, the temperature of the mixture, and the character of the road-testing technique and of the laboratory knock-rating procedure.

(2) *Detonation Characteristics of Current Engines.*—Before analyzing the factors influencing engine-fuel relationships, it seems appropriate here to point out that the 1934 Union-

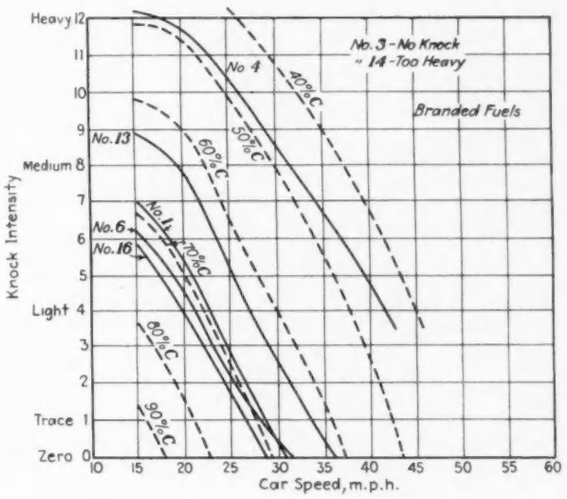


Fig. 8—Knock Intensity versus Car Speed

The solid lines represent the test fuels; the dash lines, the reference-fuel blends in per cent of C-8 in A-3

Car No. 12.
Spark advance, standard (11 deg. before top dead-center).
Air temperature, 75.1 deg. fahr.
Test conditions, hill acceleration.
Compression ratio, 5.25.
Barometric pressure, 28.86 in. hg.
Group No., average; 7, 19.
Humidity, 70.

town tests indicate that engine-detonation characteristics have not changed substantially since 1932. The average variation for all fuels in the 1934 hill-road tests is +0.36 octane number above the A.S.T.M. method, and the 1932 tests also showed a positive variation of 0.18 octane number. The average variation of the hill-road test-results for all fuels from the C.F.R. research method was —3.12 octane numbers in 1934, and —3.55 octane numbers in 1932. Table 10 expresses the same fact in terms of severity factor.

(3) *Octane Requirements of Cars.*—Fig. 6 shows the octane requirements of the cars used, based on a trace knock intensity obtained with reference Fuels A-3 and C-8. Such a stable fuel as mixtures of A-3 and C-8, and not a sensitive fuel, should be used for the direct determination of the octane number requirements of cars. This arises from the fact that, as was shown in the preceding sections, some cars as individuals rated sensitive fuels above the average rating and other cars rated them below the average. The result is that, if a sensitive fuel be employed for determining the octane number requirement of a car, the result obtained would embody whatever degree of deviation that may be characteristic of that fuel in that particular car.

Fig. 7 gives the approximate relation between knock intensity, ranging from trace to heavy, and changes in octane numbers of the fuels. From these two charts it would seem that knock intensity does not change to the same degree in all cars when the octane number of the fuel changes. The higher the octane-number requirement of the car is, the less sensitive it is to changes in the octane number of the fuel. Thus Car No. 19 is considerably less critical to a given change in octane number than is Car No. 5.

Another factor affecting the octane requirements of the cars was the weather conditions, notably the humidity, at the time of determination.

An inspection of the Uniontown data shows the degree of variation of humidity during the tests. The effect of these changes was to increase or decrease the knocking tendency of

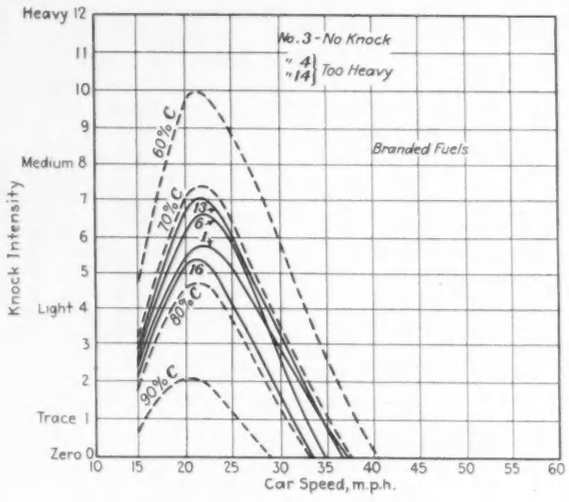


Fig. 9—Knock Intensity versus Car Speed
The solid lines represent the test fuels; the dash lines, the reference-fuel blends in percent of C-8 in A-3

Car No. 15.
Spark advance, 0 deg.
Air temperature, 71.5 deg. fahr.
Test conditions, hill acceleration.
Compression ratio, 6.5.
Barometric pressure, 28.73 in. hg.
Group No., average; 13, 16.
Humidity, 76.

the cars with decreasing or increasing humidity, respectively. While this change was quite noticeable in the octane-number requirement of the car, no apparent effect was observed in the ratings of the fuel.

(4) *Knock-Speed Characteristics of Cars.*—The Uniontown data clearly indicate that different cars may have a wide variety of knocking characteristics. The cars may be classified as follows, according to knocking characteristics:

(*a*) Cars in which both the reference and test fuels have their maximum knock intensities occurring at low speeds, Cars Nos. 12 and 13, as illustrated in Fig. 8.

(*b*) Cars in which both the reference and test fuels have their maximum knock intensities occurring at intermediate speeds, Cars Nos. 1, 2, 3, 10 and 15, as illustrated in Fig. 9.

(*c*) Cars in which both the reference and test fuels have their maximum knock intensities occurring at high speeds, Car No. 19; as illustrated in Fig. 10.

(*d*) Cars in which the knock intensities of both the reference and test fuels peak at two speeds, Cars Nos. 7, 8, 9 and 11; as illustrated in Fig. 11.

(*e*) Cars in which the maximum knock intensity of the reference fuels occurs at low speeds while the knock intensity of some of the test fuels peaks at high speed or both high and low speeds, Cars Nos. 4 and 18; as illustrated in Fig. 12.

Only one car, namely, Car No. 19, fell in classification (*c*) represented by the curve in Fig. 10, and this car rated all fuels lower than the average. This fact suggested that perhaps, when testing sensitive fuels, all ratings made in cars having a high-speed knock tend to be low. Therefore, the chart in Fig. 13 was constructed, giving the car ratings of Fuel No. 12 (b-1) plotted against the speed at which these

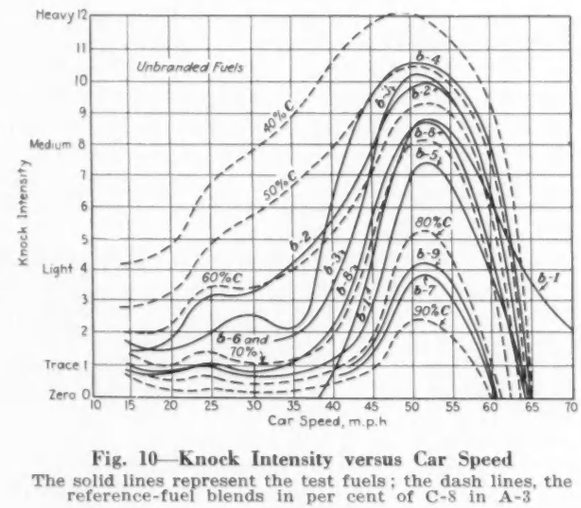


Fig. 10—Knock Intensity versus Car Speed
The solid lines represent the test fuels; the dash lines, the reference-fuel blends in per cent of C-8 in A-3

Car No. 19.
Spark advance, standard (9 deg. before top dead-center).
Air temperature, 71.1 deg. fahr.
Test conditions, hill acceleration.
Compression ratio, standard; 6.25.
Barometric pressure, 28.75 in. hg.
Group No.; 10, 21 and 24.
Humidity, 74.

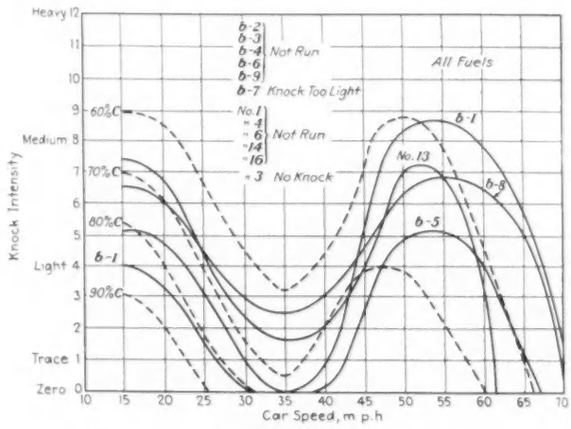


Fig. 11—Knock Intensity versus Car Speed
The solid lines represent the test fuels; the dash lines, the reference-fuel blends in per cent of C-8 in A-3

Car No. 11′.
Spark advance, 0.007 in. after top dead-center.
Test conditions, hill acceleration.
Compression ratio, 6.5.
Group No. 16.

ratings were obtained. This chart tends to confirm this belief and indicates that further analysis of the data and research on this phase of the problem might be desirable.

(5) *Knock Intensity at Which Ratings Are Made.*—As is apparent from Figs. 11 and 12, in the cases of cars falling in classes 4 and 5, for some test fuels, the observer had to compare the intensity of a knock occurring at high speeds with knock intensities occurring at low speeds on reference fuels. It was observed from the data that when fuel-car combinations of classes 4 and 5 were used, the rating obtained with a high knock intensity was lower than that obtained with a low intensity. This may account for some of the wide spreads obtained with a sensitive fuel such as No. 12 (b-1). For instance, the rating of this fuel in Car No. 4 was 101-per cent C-8, whereas that in Car No. 7, in which a higher knock intensity was used, was 68-per cent C-8. With the same fuel, Cars Nos. 4 and 6, which were of the same make, gave deviations of +17 for Car No. 4 and −11 for Car No. 6, the intensity of the latter being considerably greater.

Tests conducted along this line on Car No. 11′ are il-

lustrated by the curve in Fig. 14. The intensity of knock was decreased by retarding the spark. At the high intensity the maximum knock of the test fuel occurred at high speeds. As the intensity was decreased by retarding the spark, the relative intensity of the high-speed knock compared with the low-speed knock decreased until, finally, the high-speed knock disappeared entirely. Thus there is an indication that some ratings obtained at high knock intensity in this particular car would be lower than ones obtained at low intensities. This factor was further investigated by varying the intensity of knock by using one fuel with and without the addition of lead tetraethyl. This gave a direct comparison of knock intensities resulting from changes in octane number rather than from changes in spark setting. Both methods gave similar results indicating further, but not necessarily proving

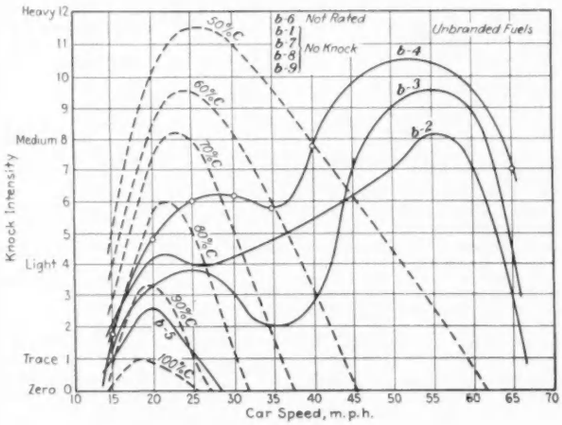


Fig. 12—Knock Intensity versus Car Speed

The solid lines represent the test fuels; the dash lines, the reference-fuel blends in per cent of C-8 in A-3

Car No. 4.
Spark advance, 11 deg. before top dead-center.
Test conditions, hill acceleration.
Compression ratio, standard; 6.25.
Group No. 16.

conclusively, that knock intensity rather than spark advance is the critical factor. In this connection, it appears that cars in which the test fuel and reference fuel have the same type of curve are more nearly alike in octane number requirements than those in which the test fuel and reference fuel have differently shaped curves.

Detonation Research

(1) *Laboratory Apparatus and Technique.*—In the field of detonation research, including the improvement of test methods and the securing of more harmonious engine-fuel relations, that section relative to laboratory test equipment and procedure offers the readiest approach. The Cooperative Fuel Research at present embraces a number of projects directed toward the goal of securing more accurate laboratory knock ratings which, while not immediate outgrowths of the work at Uniontown, will contribute to the solution of the problems presented by it. These projects include the following:

(1) Preparation of a more precise definition of the procedure for setting test conditions, particularly in respect to the knock intensity employed.

(2) Determination of the influence of altitude upon knock ratings

(3) Determination of the influence of exhaust-system characteristics upon knock ratings

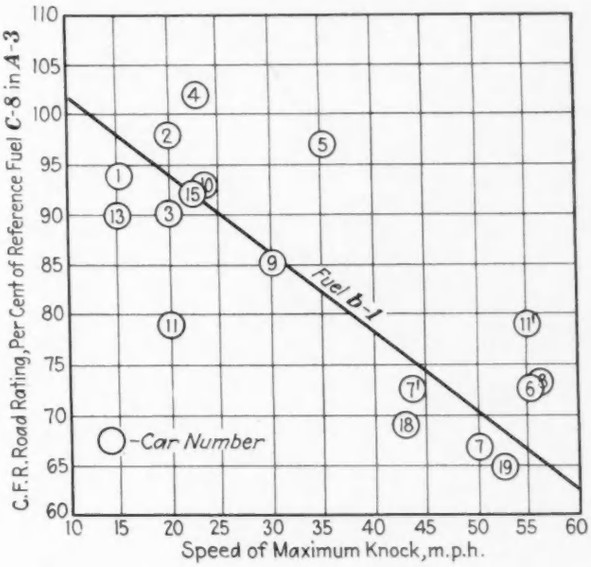


Fig. 13—Ratings of Fuel b-1 Plotted against Car Speeds at Which These Ratings Were Obtained

(4) Determination of the effect upon ratings of Uniontown fuels of reducing mixture temperatures by stages from 300 to 200 deg. fahr.

(5) Improvement of the bouncing-pin indicator.

Other phases of laboratory testing technique which might profitably be investigated but for which no definite provision has as yet been made are:

(6) Effect of variation in the cylinder construction of the knock-testing unit

(7) Modification of the Research Method so that Research Ratings, useful as a measure of fuel sensitivity, may be obtained with the standard A.S.T.M.-C.F.R. knock-testing unit

(8) Methods by which unconventional fuels such as benzene may be brought into line in respect to correlation between laboratory ratings and behavior in multi-cylinder engines in representative service

(9) Securing a reference fuel of more suitable sensitivity

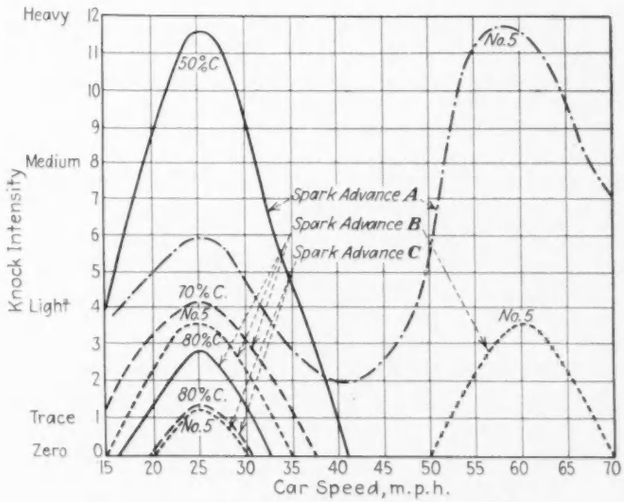


Fig. 14—Effect of Knock Intensity on Ratings

The curves represent reference-fuel blends in per cent of C-8 in A-3, and Fuel No. 5, for Car No. 11

characteristics with respect to similarity in behavior in cars and the single-cylinder laboratory test-unit

(10) Suitable specifications for normal-heptane and iso-octane

(2) *Road-Test Procedure.*—A distinct advance was made in the technique of road testing during the 1932 cooperative project at Uniontown through the introduction of the method of securing ratings at maximum knock intensity, which has been incorporated in the C.F.R. Road-Test Procedure. However, need has been indicated for further improvement in the precision of individual-car knock-ratings, which would be a great aid in the important investigation of the reasons underlying the differences in the behavior of sensitive fuels in different cars. Some lines along which investigation might profitably be made are the following:

(*A*) Effect on knock rating of: (*a*) Knock intensity at which the rating is made; (*b*) speed at which knock is measured; (*c*) controllable engine adjustments, such as spark advance and mixture ratio; (*d*) mixture temperature; (*e*) atmospheric conditions.

(*B*) Provision for a source of supply of a pair of representative and reasonably reproducible experimental gasolines, one of high sensitivity and the other comparable with the average commercial gasoline. Such standardized gasolines might be useful not only in studies of the behavior of fuels in commercial engines but also in the efforts to reach a more satisfactory standardization of the laboratory engine and procedure. The establishment of such standard experimental gasolines would carry still further forward the work of putting testing organizations on a uniform or comparable basis, to which the establishment of the present reference fuels contributed so materially.

(*C*) Elimination of the personal factor from car ratings by the use of instruments, which is dependent upon the development of dependable instrumentation for use in cars on the road. Some investigation of this matter was made during the 1934 Cooperative Road Tests and further research is now in progress.

(3) *Fuels.*—(*a*) Much research on the characteristic of fuel sensitivity is now in progress in individual laboratories and the application of the concept of the engine severity factor to existing data developed both by individual laboratories and by cooperative tests will undoubtedly prove a fruitful source of further knowledge on this subject; and (*b*) obtaining and circulating data which will serve the purpose of periodic national surveys of commercial motor fuels would be of assistance to manufacturers in adapting their engines to available fuels.

(4) *Engines.*—The necessity for studying the effect of the various factors of test procedure and conditions enumerated above is emphasized by the frequent failure of attempts in analyzing the 1934 and other test data to reveal conclusively any very definite effect on such engine-design factors as cylinder-head and piston structural material, shape of combustion chamber, type and location of spark plugs, inlet and exhaust manifolding, valve construction and mechanism, cylinder bore, cooling, car speed of maximum knock, and other pertinent features, probably because of inadequate control of test conditions or lack of understanding of the relative importance of each specific item.

Many projects resulting from a study of the Uniontown tests will undoubtedly be carried out by individual laboratories and the Cooperative Fuel Research Committee will encourage all such original investigations as contribute to its primary purpose of better adapting fuels to engines and engines to fuels.

Appendix

The C.F.R. Road-Test Method for determining the relative antiknock value of motor fuels.

Authority.—At its meeting at Uniontown, Pa., Aug. 17, 1932, the Detonation Subcommittee of the Cooperative Fuel Research Committee adopted the hereinafter described method of conducting antiknock tests in automotive vehicles on the road. The method was approved by the Cooperative Fuel Research Committee at its meeting on Sept. 12, 1932. Its essential features were published in the paper "Correlation of C.F.R. Laboratory Knock Ratings with Behavior of Motor Fuels in Service"[6], by C. B. Veal, H. W. Best, J. M. Campbell and W. M. Holaday.

Scope.—The method is not designed to determine octane numbers, but for the purpose of determining the relative antiknock value of fuels in motor vehicles on the road. The method involves a comparison between the fuel to be rated and reference fuels of known antiknock value.

Location for Tests.—An essential for securing useful data in such a test is a long enough stretch of highway either of sufficiently uniform grade or sufficiently level to insure that equilibrium engine conditions can be achieved before data are taken and during the test for a length of time adequate to secure reasonable reproducibility of data.

Equipment.—A second essential is that the vehicle be maintained in good mechanical order so that changes in mechanical conditions during test operations may not materially affect the value of the test data for any fuel. Manufacturer's standard adjustments of the various mechanisms of the vehicle are to be preferred. In view of the importance of comparative speed, speedometers or other speed-measuring instruments used should be frequently calibrated. Any deviation from manufacturer's standard and adjustments should be reported.[7]

Supplies.—Two reference fuels are essential, one of high octane number and one of low octane number. They should be of a type which does not change in performance characteristics within a reasonable time in storage or in use and of a volatility requiring no change in the induction system from the adjustments conventional for ordinary motor fuels.[8]

Test Conditions.—Slow acceleration or slow deceleration, in high gear with wide-open throttle shall be employed. The rate of acceleration or deceleration may be maintained "slow" by highway grade, by brakes, or by towing another vehicle on

---

[6] See *Proceedings of the American Petroleum Institute*, Section III, p. 139.

[7] Air-fuel ratio adjustment of the carburetor and spark-advance setting are examples of adjustments referred to and are of particular importance in securing dependable results.

A useful fuel-supply installation comprises a flexible metal tubing leading from the interior of the car to an electrically operated fuel pump mounted conveniently. Connections between this fuel pump and the carburetor and between the metal line within the body of the car and the fuel supply may be made with rubber hose or metal tubing as is most convenient. Portable containers for suitable mixtures of reference fuels are recommended so that the fuel supply can be selected readily from any container and changes made with a minimum of delay in clearing a fuel line. Usual precautions against fire and loss of volatile vapors should naturally be employed.

[8] To permit the . . . . interchange and comparison of the test data, it is generally desirable to employ secondary reference fuels which are in common use. Two such reference fuels, *A* and *C*, are commercially available through the Standard Oil Co., N. J. These fuels have octane numbers of approximately 48 and 76, respectively, and calibration curves are furnished with them as determined in accordance with the C.F.R. Motor Method, giving octane numbers of the fuels blended with each other and with benzene and tetraethyl lead. They may be ordered through the Standard Oil Development Co., 26 Broadway, New York City.

To conform to the requirements for stability in performance, lead tetraethyl is recommended as a knock suppresser when the fuel under test is of higher antiknock value than that of the high antiknock reference fuel.

a level road. When comparing two fuels, the load moved and the rate of acceleration or deceleration of the test vehicle shall be maintained as nearly constant as conditions permit.

Substantially, equilibrium conditions for the engine should be secured before each run upon which data are to be taken and maintained until the throttle is opened wide for the test run. With the vehicle in high gear, the throttle shall be opened fully in one motion without lag, and data may be taken as promptly as the accelerator-fuel reserve, if any, is consumed. Operation for 100 yd. should be employed to accomplish this if it is not convenient to verify the minimum distance required.[9]

Taking of Data.—Engine knock audible to the observers is essential for making comparisons between reference and test fuels. The knock intensity produced by various mixtures of the reference fuels at speeds in the range from 15 to 50 m.p.h. should be determined and compared with the knock intensity, produced by the fuel under test, at the same intervals of road speed.

Alternate runs of the test fuel and different mixtures of the reference fuels shall be made, noting the knock intensity for each fuel at intervals of 5 m.p.h., until a mixture of the reference fuels is found which develops a maximum knock intensity identical with the maximum knock intensity developed by the test fuel, irrespective of the speed at which such knock intensities are developed. Tests must be repeated until all observers are agreed as to the speed at which each fuel develops maximum knock intensity, and as to the selection of the particular mixture of reference fuels developing a knock intensity equal to that produced by the test fuel.[10]

Experience has shown that there are many advantages in having the identity of the reference fuels, as well as the sample under test, unknown to the operators making the test. Preferably, therefore, all fuel samples, test and reference, should be prepared by someone other than those making the actual rating, and should be given code numbers known only to the individual preparing them.

Expression of Results.—The road knock-rating of the test fuel is the same as that of the reference fuel mixture which it matches in maximum knock intensity.

[9] In conducting tests on a single vehicle, it should be borne in mind that not only different vehicles rate the same fuel differently but different fuels act differently in the same vehicle. (See Figs. 1, 3 and 4.) A number of vehicles is desirable if broad conclusions are to be drawn from the test results.

[10] A convenient method of making the necessary comparisons employs a graph where the coordinates are the intensity of knock and speed in miles per hour, respectively. The ordinate may consist of the terms light, medium, heavy; 1, 2, 3; *a*, *b*, *c*, and the like, as desired. The abscissa should be laid off from the intercept in increments of 5 m.p.h. over the speed range of the test. (See Fig. 2.) The points may be plotted as promptly as each run is completed on a fuel, or a number of alternate runs on test fuel and various mixtures of reference fuels may be plotted to determine if a bracket has been secured. With mixtures of reference fuel of respectively slightly higher and lower antiknock value than that of the test sample, the sample will be bracketed on the graph at its maximum knock intensity.

To match the test sample actually it is necessary that its maximum knock-intensity peak on the graph be on a level equal with that of the mixture of reference fuels it matches. Blends of reference fuels should be made up in steps equivalent to about 5 octane numbers for convenience in securing the bracket. Actual matching blends can also be made for confirmation of the precise road knock-rating of the test sample.

Choosing Make of Truck

VARIOUS "rating charts" covering largely the design, material and workmanship of motor trucks, have been recommended. I believe that the average operator must rely largely on his cost records, his records of road failure, and his records of time out of service as a basis of his judgment as the *price* and *quality* of the vehicle. Incidentally such tabulations, plus records of frequency of sale of repair parts, should be of vast interest to the designing engineer. What an interesting chapter a "Buyers' Guide" would have, if it contained, for a given industry a mass record of time out of service because of mechanical failure, and of road breakdowns—by make, size, and type of use!

The buyer, consciously or not, rates a vehicle before he buys it, but I do not believe that the average truck owner is equipped to rate comparative specifications except in terms of the above factors. Unless matters of financing force a compromise, the factor of *price* should naturally be rated in terms of *transportation cost,* over a potential mileage or time life set up on a basis of experience data, giving proper consideration to obsolescence and other factors discussed in this paper.

It is needless to elaborate on the importance of sizing up the purveyor from the standpoint of

(1) service availability and cost.

(2) probable permanence as a manufacturer of trucks.

But there is one highly important item which I have never seen in a sales manual; and that is the unwritten, but I fear not unrecognized principle of salesmanship "Put the customer under obligations to you!" There would seem to be more than one approach in the application of this principle. One of these, however, leaves no headachey customer painfully thumbing the dictionary to brush up on the meaning of those imposing Latin words "Caveat Emptor"; rather it leaves him with a definite feeling of obligation because of worthwhile advice and services rendered.

There are salesmen (and may their tribe multiply) who have schooled themselves vocationally into a position of being able to discuss intelligently the operator's problems in his own language; not merely to expound the virtues of their wares, but also to so insinuate themselves into the customer's confidence and respect as to be welcomed as cooperators, not peddlers. Such salesmen—men who keep uptodate on transportation problems, men who can present a refreshing and enlightening outside point of view, and who are fact-finders first, salesmen afterwards, perform a genuinely useful function in the industry. They are purveyors of transportation who deserve from both buyers and manufacturers more recognition than they receive. If there were more of them, truck salesmanship would become relatively painless. As for the rest, I think no one would object should they care to jeopardize their amateur standing by throwing away their carpet slippers and finding out what it's all about.

Another factor worth consideration in determining upon make of vehicle to purchase is that of the manufacturer's policy relative to interchangeability of parts and units as between models in the line, and in the design of new models. In fleets wherein unit replacement can profitably be included in the maintenance system this point is of considerable importance, for obvious reasons.

Excerpt from paper entitled "How To Buy a Truck" presented at the Annual Meeting, Detroit, Jan. 14, 1935, by T. L. Preble, Tide Water Oil Co.

Farewell to the Horseless Carriage

By Elliott G. Reid

Guggenheim Aeronautical Laboratory
Stanford University

THIS critical study of the possibilities of improving automobile performance and economy by aerodynamic refinement is begun by demonstrating the analogy between motor-car air-resistance and airplane parasite-drag. An example is then cited to illustrate the benefits of aerodynamic research in the latter field and to point out the potentialities of similar work in the former.

Consideration of practical requirements and limitations in an analysis of motor-car air-resistance leads to the selection of a rear-engine arrangement as the most promising type and to the prediction that its air resistance will approach one-fourth that of conventional cars.

This prediction is confirmed by the results of wind-tunnel model-tests. Full-scale replicas of the models tested would provide adequate passenger accommodations and engine space without exceeding accepted overall lengths. Combination of the test results with reliable rolling-resistance data indicates the possibility of reducing current power-requirements by 19 to 55 per cent at speeds of 20 to 60 m.p.h.

The author expects rapid obsolescence of the present or "horseless-carriage" type to follow the appearance of streamlined, rear-engine motor-cars.

ONE-THIRD of a century has elapsed since the motor car began to displace the horse and buggy as a private conveyance. Our smug satisfaction in the completeness of this replacement is, to put it in the kindest way, more to be pitied than censured. The pity is that, having lost sight of the forest on account of the trees, we have been gullible enough to think of the process of replacement as complete, whereas, in reality, it is not more than half finished. To be sure, the horse has disappeared and his place has been taken by the highly developed internal-combustion engine. On the other hand, despite its luxurious modernization, the carriage is still with us and it retains most of its century-old external crudeness. It may be a little severe to compare 1934 automobiles with horse-drawn milk-wagons, but the fact remains that they are still only "horseless carriages" and not vehicles of an entirely new type.

A situation which is rather hard to explain comes to light when we compare the development of the automobile with that of other vehicles of transportation. The boat, train, airship and airplane, as well as the automobile, move through fluids, either air, water or both. The earliest types of all these vehicles had extremely crude external shapes; the latest forms of all but the automobile have smooth contours and tapered tails designed to minimize their resistance to motion through fluids. This backwardness in a single member of an otherwise progressive group would seem to confirm the suspicion of an unfortunate hereditary influence.

It is undoubtedly true that the greatest deterrent to exhaustive studies of the aerodynamics of passenger automobiles is the generally accepted belief that air resistance, at all but very high driving speeds, is either inconsequential or not materially reducible by practicable methods. Countless repetitions of this doctrine are to be found in newspapers, technical journals and reports to the stockholders of automobile companies.

A contrary opinion is held, however, by a minority group which is largely composed of aeronautical engineers. Let me hasten to add, before someone refers to the pot which called the kettle black, that it is entirely safe to invite the members of this group to cast the first stone because they have shown a

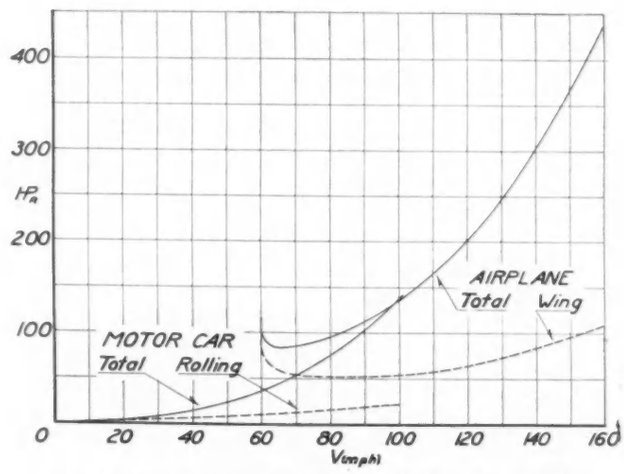


Fig. 1—Power Requirements of Motor Car and Airplane; Gross Weight, 4000 Lb. Each

[This paper was presented at the Annual Meeting of the Society, Detroit, Jan. 16, 1935.]

similar disdain toward the parasite drag of their airplanes until quite recently. However, since motor-car air-resistance can be shown to be the analogue of airplane parasite-drag, the remarkable reductions of the latter which have been effected through recent aerodynamic research make it seem absurd to think that similar developments are not to be expected in the automobile field.

It is the plan of this paper to establish the above-mentioned analogy, to illustrate recent aeronautic progress in the analogous field, to analyze the possibilities of aerodynamic improvement of the motor car, to describe experiments made to confirm this analysis and to discuss the practical significance of the results.

Analogy Between Automobile and Airplane

It is customary and convenient to consider the total resistance of both automobiles and airplanes to be made up of two components. The automobile experiences rolling and air resistances. The total drag of an airplane is usually decomposed into wing-drag and parasite-drag; that is, that of all parts of the machine except the wing.

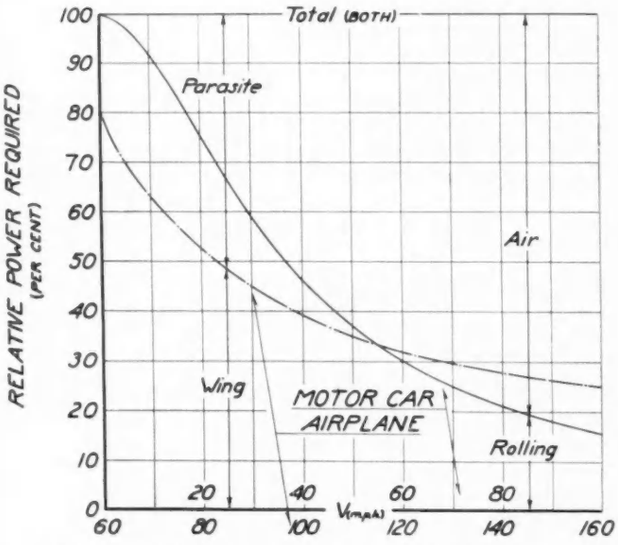


Fig. 2—Relative Power Requirements Derived from Fig. 1

Curiously enough, curves of component and total power requirements for the two vehicles (Fig. 1) exhibit scant resemblance and this may be the principal reason that a very significant similarity between the two cases has not been recognized. A surprising correlation is discovered, however, when the components are plotted as percentages of the totals and the velocity scales are shifted to bring the minimum speeds into coincidence (Fig. 2).

If the wing-drag and rolling resistance be accepted as unavoidable evils—or, at least, items which are not susceptible to modification except by changes of weight or maximum dimensions or both—it becomes evident that the parasite-drag of the airplane and the air resistance of the automobile are not only analogous but are also quantities of the same order of relative magnitude which exhibit similar variations with speed. The validity of this analogy is strengthened by consideration of the fact that these components would constitute the sole power requirements of the two vehicles if both could be supported, while in horizontal motion, without the expenditure of power for that purpose.

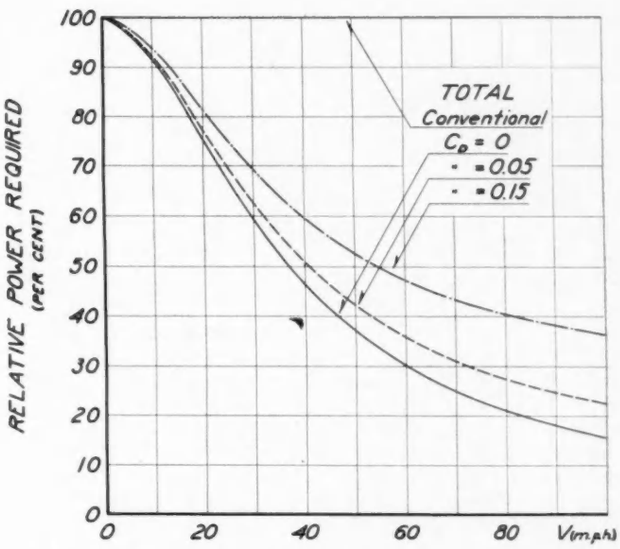


Fig. 3—Effect of Air Resistance on Motor-Car Power-Requirements

It follows that corresponding improvements of economy and performance can be effected by proportionate reductions of the analogous components of resistance. The illustration which follows will demonstrate what has been accomplished in the aircraft field and should give some indication of what may be expected when similar progress is made in motor-car design.

Example of Aircraft Refinement

Ten years ago last autumn, the most unorthodox airplane of its time attained a speed of 216 m.p.h. to win the Pulitzer Trophy. Criticized and ridiculed when it appeared, the Verville-Sperry racer is now recognized as the prototype of the modern, high-speed transport; it was a low-wing, cantilever monoplane with a retractable landing gear.

Today, several airlines make use of the Lockheed "Orion," which is a machine of the same type and approximately the same engine power as those of the 1924 racer. Its top speed is more than 216 m.p.h., its weight and wing area are more than twice those of the Verville-Sperry and, in place of one pilot in an open cockpit, it carries a pilot and six passengers in a large cabin.

This evidence demonstrates that aerodynamic improvements have made it possible to increase greatly the size and weight of an airplane without having to sacrifice speed or to increase power. Although such specific examples, of which there are many, may not be matters of common knowledge among automobile designers, they, as a group, are certainly aware that within the last ten years great improvements have been effected through aerodynamic research. Two very important facts, however, seem to have escaped general appreciation. The first is that a representative 1924 airplane possessed a high degree of aerodynamic refinement as compared to that of the current motor car. The second is that improvements of the same order as those cited above may be effected by the application of known aerodynamic principles to the redesign of the 1934 automobile.

Analysis of Possible Aerodynamic Improvement

The automobile power curves of Fig. 1 refer to a conventional sedan which is assumed to have a weight of 4000 lb.,

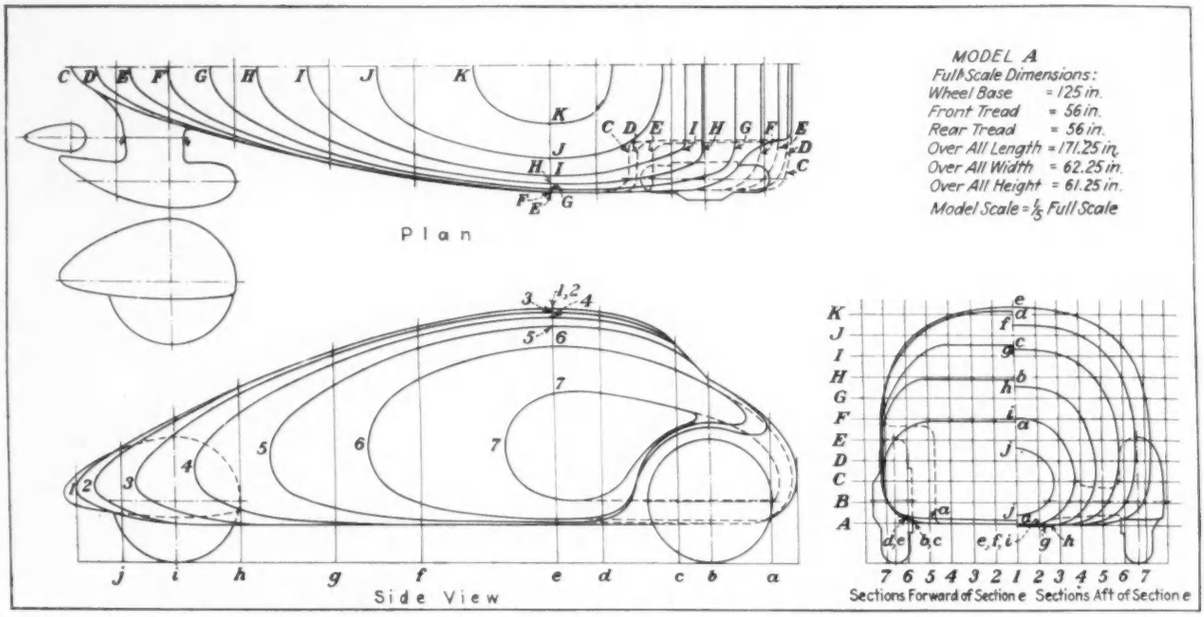

MODEL A
Full Scale Dimensions:
Wheel Base = 125 in.
Front Tread = 56 in.
Rear Tread = 56 in.
Over All Length = 171.25 in.
Over All Width = 62.25 in.
Over All Height = 61.25 in.
Model Scale = 1/8 Full Scale
Plan
Side View
Sections Forward of Section e
Sections Aft of Section e

Fig. 4

a frontal area of 28 sq. ft., an air resistance coefficient[1] $C_D = 0.607$ ($K = 0.00155$) and the rolling resistance defined by the equation[2]

$$D_r = \frac{W}{1000}(11.6 + 0.0867\,V) \qquad (1)$$

in which D_r is the rolling resistance in pounds, W the weight in pounds, and V the velocity in miles per hour. These curves define the power which must be delivered to the clutch; they are, however, not entirely suitable for the proposed analysis. Let us, therefore, refer to the relative power curve which appears as a solid line in Fig. 3.

The absolute and unattainable limit of aerodynamic refinement corresponds, of course, to the complete elimination of air resistance. By reference to the ordinates of the rolling-power curve it is seen that, under this hypothetical condition,

[1] Absolute system (non-dimensional) coefficients are used in this paper because they are less cumbersome than those of the "engineering system," require no conversion for use with metric units and have a readily understood physical significance.

$$C_D = \frac{D}{Sq}$$

D = resistance or drag, lb.
S = frontal area, sq. ft.
q = dynamic pressure, $\frac{\rho V^2}{2}$, lb. per sq. ft.
ρ = mass density of air, slugs per cu. ft.
V = velocity, ft. per sec.

Physical interpretation: When $C_D = 1.0$, D is equal to the product of frontal area and dynamic pressure.

[2] Average of Lockwood's chassis-dynamometer test-results. See *Proceedings of the National Research Council*, eighth annual meeting of the Highway Research Board, 1928; Air Resistance of Automobiles, by E. H. Lockwood.

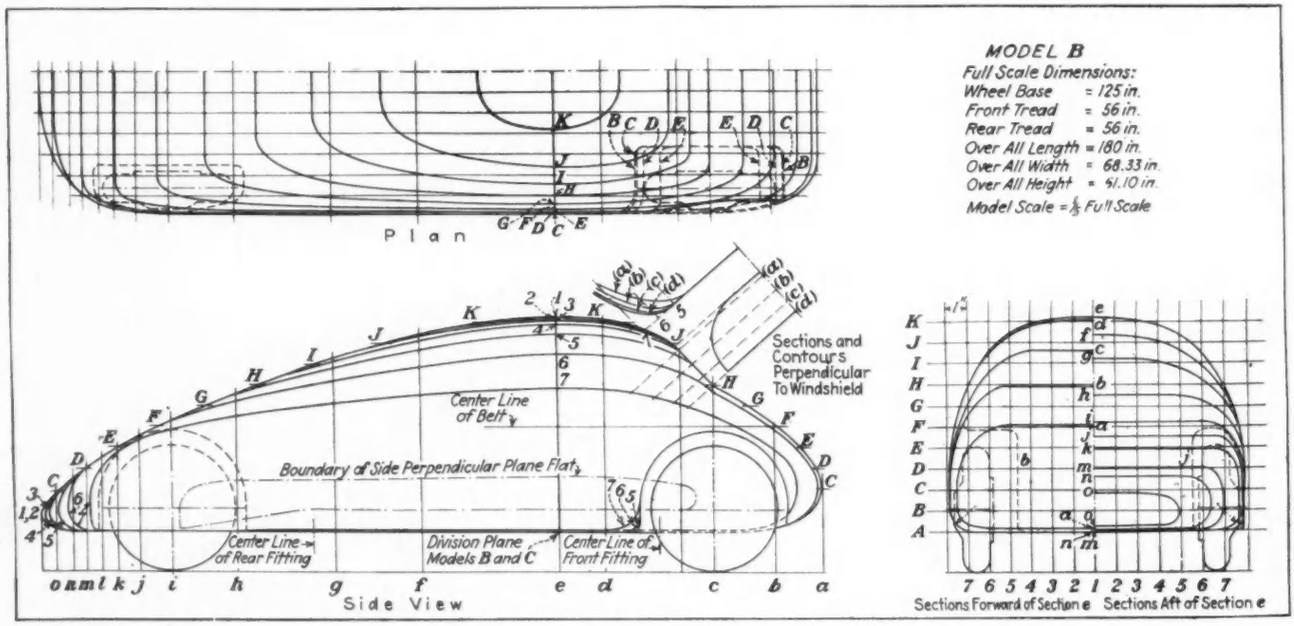

MODEL B
Full Scale Dimensions:
Wheel Base = 125 in.
Front Tread = 56 in.
Rear Tread = 56 in.
Over All Length = 180 in.
Over All Width = 68.33 in.
Over All Height = 61.10 in.
Model Scale = 1/8 Full Scale
Plan
Sections and Contours Perpendicular To Windshield
Center Line of Belt
Boundary of Side Perpendicular Plane Flat
Center Line of Rear Fitting
Division Plane Models B and C
Center Line of Front Fitting
Side View
Sections Forward of Section e
Sections Aft of Section e

Fig. 5

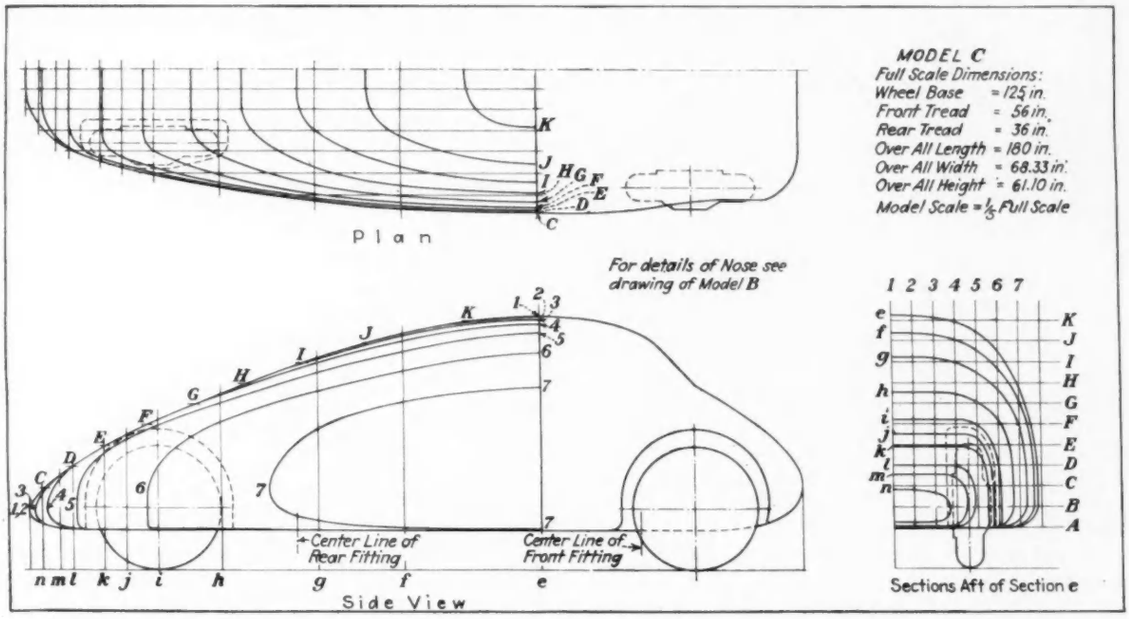

MODEL C
Full Scale Dimensions:
Wheel Base = 125 in.
Front Tread = 56 in.
Rear Tread = 36 in.
Over All Length = 180 in.
Over All Width = 68.33 in.
Over All Height = 61.10 in.
Model Scale = 1/5 Full Scale
Plan
For details of Nose see drawing of Model B
Center Line of Rear Fitting
Center Line of Front Fitting
Side View
Sections Aft of Section e

Fig. 6

existing power requirements might be reduced by amounts ranging from about 25 per cent at 20 m.p.h. to almost 80 per cent at 80 m.p.h. Although this is an ideal condition, practical limits are not so far removed therefrom as many seem to think.

As a step toward the establishment of a practical goal for aerodynamic development, let us assume that a motor car might be so designed that its drag coefficient would be equal to that of a well-shaped airship-hull. Under this condition $C_D = 0.05$; a corresponding curve appears in Fig. 3. It is difficult to believe that any such degree of perfection could be attained in a vehicle which must have at least partially exposed wheels, a relatively flat under-surface and some practically unavoidable irregularities of contour. Let us, therefore, be generously conservative; suppose that we assume that our hypothetical car will have an air resistance equal to that of an airship hull which has three times the frontal area of the automobile. This assumption corresponds to $C_D = 0.15$ which, by the way, is about one-fourth of the value for a present-day motor-car; a curve for $C_D = 0.15$ also appears in Fig. 3.

This last curve deserves special attention. It not only represents a conceivably attainable condition but it approximates the results obtained by wind-tunnel tests of a 1/5-scale model of a streamlined, rear-engine sedan of practical form and dimensions.

Experimental Confirmation

General Design Consideration.—In place of the usual comprehensive resumé of related work, only the salient facts

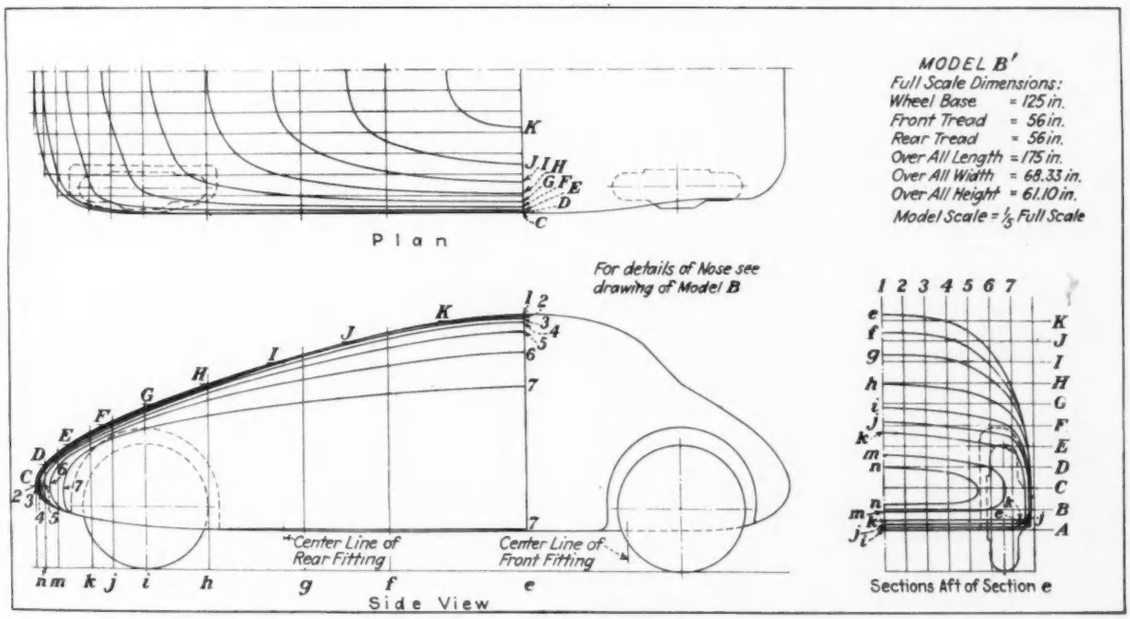

MODEL B'
Full Scale Dimensions:
Wheel Base = 125 in.
Front Tread = 56 in.
Rear Tread = 56 in.
Over All Length = 175 in.
Over All Width = 68.33 in.
Over All Height = 61.10 in.
Model Scale = 1/5 Full Scale
Plan
For details of Nose see drawing of Model B
Center Line of Rear Fitting
Center Line of Front Fitting
Side View
Sections Aft of Section e

Fig. 7

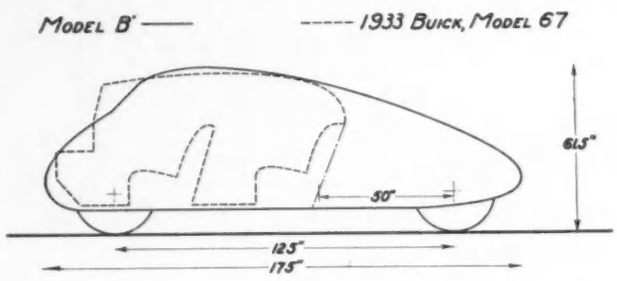


Fig. 8—Central Longitudinal Profile—Model *B'*

established by previous experiments will be restated here. A brief bibliography is appended. The air-resistance characteristics of conventional sedans have been thoroughly established by numerous full-scale and model tests[3]. Professor Lay's experiments[4] indicate that a major reduction of air resistance—approximately 80 per cent—may be effected by eliminating excrescences and irregularities from the contours of the conventional car and by providing it with a very long tapered tail, the body length being about 2.6 times the wheel-

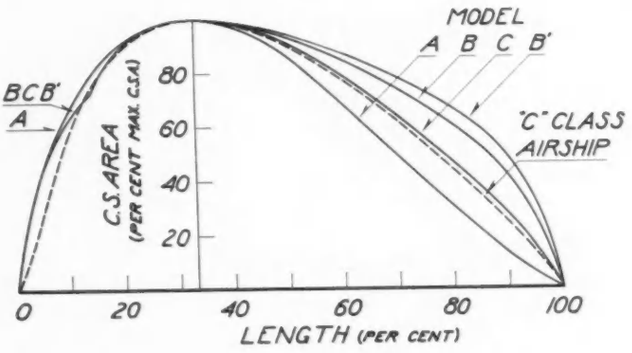


Fig. 9—Distribution of Cross-Sectional Area—Airship Hull and Motor-Car Models

base. A compromise design for the conventional chassis, also evolved by Professor Lay, has only half the air resistance of current sedans and its overall length, including bumpers, is approximately 1.75 times the wheelbase. The average 1934 automobile has an overall length of about 1.63 times its wheelbase.

It is not surprising that manufacturers have failed to adopt these design features, in spite of their aerodynamic advantages, because any considerable increase of present overall lengths would lead to difficulties of driving, parking and housing which would preclude general acceptance of such cars. It is, therefore, apparent that if aerodynamic refinement of motor cars is to have practical value under present conditions, it must be effected without increasing current overall dimensions.

If this criterion be accepted, it requires only brief examination of one fundamental aerodynamic principle to select the most promising line of development. It is a well-established fact that if the form of the largest transverse profile and the length of a body are specified, a minimum of air resistance will be experienced when the largest cross-section is located somewhat forward of mid-length and the after portion is gently tapered toward a point or edge; that is, when the taper of the rear portion is less abrupt than that of the forward one. As applied to the automobile problem, this principle has but one possible interpretation: The passenger compartment—largest transverse profile—must be located nearer the front than the rear of the car if minimum air resistance is to be obtained. Thus the rear-engine type is clearly indicated.

Although a number of experimental rear-engine cars have been built, all of them appear to have seriously objectionable features. Among these faults, the most common one is prohibitive overall length. Moreover, in most cases the centers of gravity are very far aft. In the example of greatest aerodynamic refinement, the rear engine is combined with a front drive, thereby sacrificing the potential advantage due to the lowering of the passenger compartment which is possible with a rear drive. Due consideration of these and other objections led to the apparently inevitable question: Why not turn the conventional chassis end-for-end, use forward steering and rear drive, move the passenger compartment forward and enclose the rearranged volumes with a streamlined body? To summarize a long story of measuring, sketching, modelling in clay and the like, no reason was found for not doing just those things.

The design, building and testing of the models which are described below constituted the thesis investigation of Messrs. D. B. Bates and E. F. Stoner who were, last year, graduate students of mechanical engineering at Stanford University[5]. The program was suggested by the writer and carried out under his supervision.

Models

The models of this series are of 1/5 linear-scale and represent sedans of 125-in. wheelbase and 56-in. tread except in the case of Model *C*. Detailed drawings of the models are reproduced as Figs. 4 to 7. The central longitudinal profile of the final model, *B'*, is shown in Fig. 8; a corresponding section of the passenger compartment of a typical five-passenger sedan (1933) of 127-in. wheelbase is superimposed to illustrate the satisfaction of passenger-space requirements.

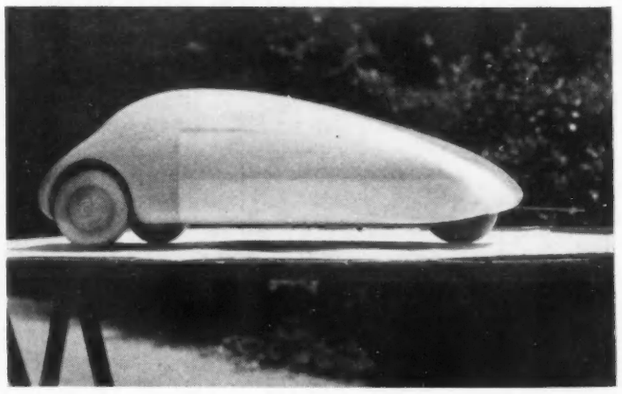


Fig. 10—Model *B'* with Left Rear Wheel Removed

[3] See *Proceedings of the National Research Council*, eighth annual meeting of the Highway Research Board, 1928; Air Resistance of Automobiles, by E. H. Lockwood. See also S.A.E. TRANSACTIONS, vol. 28, pp. 144 and 177; Is 50 Miles per Gallon Possible with Correct Streamlining? by W. E. Lay. See also S.A.E. TRANSACTIONS, vol. 26, p. 333; Streamlining Applied to Automobiles, by Othmar K. Marti.

[4] See S.A.E. TRANSACTIONS, vol. 28, pp. 144 and 177; Is 50 Miles per Gallon Possible with Correct Streamlining? by W. E. Lay.

[5] See Thesis (Engineer) Stanford University, June, 1934; An Aerodynamic Study of Bodies for Passenger Automobiles, by D. Barker Bates and Eliot F. Stoner.

Model *A*, the first and most grotesque member of the series, might be called "an airship hull on wheels.". The distribution of cross-sectional area along the length was patterned after that of the basic hull-form of the U. S. Navy C-class airship, a form known to have very small resistance; see Fig. 9. The rear wheels and axles are enclosed within streamlined fairings which are generously filleted in accordance with present aircraft practice; the front wheels are set in recesses which are open on the sides.

An exhaustive study of this first model laid the foundation for the design of Models *B* and *C*. In Model *B*, the tail was broadened sufficiently to enclose rear wheels of 56-in. tread. Model *C* was designed in anticipation of a large increase of body resistance with the widening of the tail, and its rear tread is equivalent to only 36 in. in full scale. The forms of the nose and of the front wheel-pockets were somewhat improved in these models.

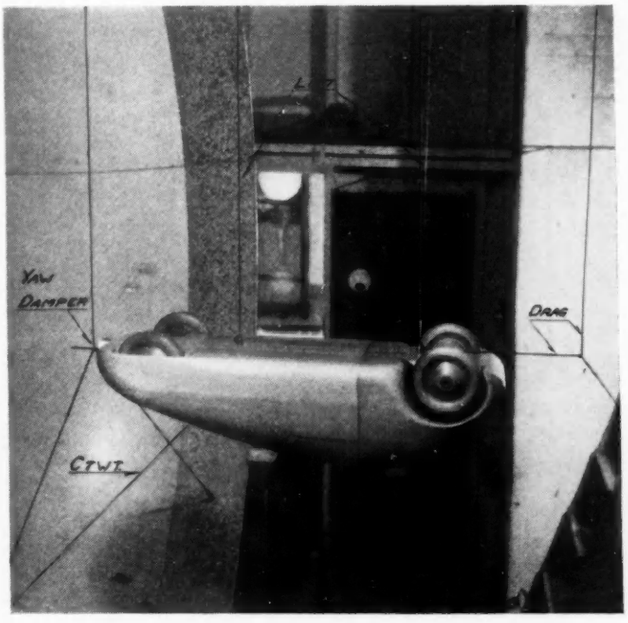


Fig. 11—Wind-Tunnel-Test Set-Up (Model *B*)

Model *B′* is simply an altered form of Model *B*. The modification consisted in shortening and elevating the tail. Fig. 10 shows this model with one rear wheel removed in order to expose the under-body contours.

The models were carved from pre-shaped, laminated blanks of sugar pine and finished with several rubbed coats of clear lacquer. The maple wheels reproduce such details as tire contour and brakedrum form. Lest anyone think of them as tiny miniatures, the models are about 3 ft. long and weigh 40 to 50 lb. apiece.

Apparatus and Procedure

The experiments were conducted in the 7.5-ft. wind-tunnel of the Guggenheim Aeronautic Laboratory at Stanford University. The models were supported and the forces transmitted to the balances by the system of wires illustrated in Fig. 11. The force-measuring apparatus made it possible to

[6] See S.A.E. TRANSACTIONS, vol. 28, pp. 144 and 177; Is 50 Miles per Gallon Possible with Correct Streamlining? by W. E. Lay.

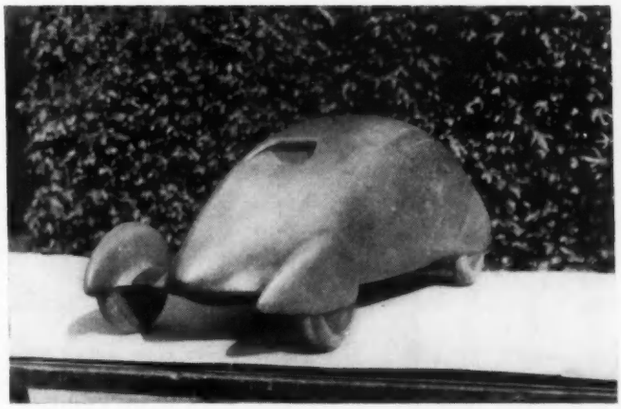


Fig. 12—Model *A* with Rear-Wheel "Spats" and Closed Front-Wheel Pockets

determine the resistance, the lift and the location and inclination of the resultant air-force vector with respect to the longitudinal profile of the model.

The tare resistance was determined by the method of duplication; that is, a second complete set of wires and fittings is added to the model and the difference between the drag in this condition and the original one is taken as the tare. This method has the unique advantage of duplicating the interference effects and the velocity distribution which exist under test conditions.

No simulation of ground effect was attempted. In place of an extended discussion on this point, it may be sufficient to say that if the unrestricted flow beneath a model is practically parallel to an imaginary ground plane, it is obvious that the introduction of such a plane—which, for complete ground simulation should move at wind speed with respect to the model—can not materially alter the unrestricted flow unless the lower-surface boundary-layer has a thickness of the order of the ground clearance. Since the models experienced relatively small lifts, had flat, smooth under-surfaces with well-rounded edges and had ground clearances equal to about 6 per cent of the overall lengths, it is believed that this simplification is justifiable. Evidence supporting this conclusion is furnished by Lay's work[6]; he found that the drag determined by a free-stream test of a certain model was only 6 per cent less than that obtained by the duplicate-model—mirror-image

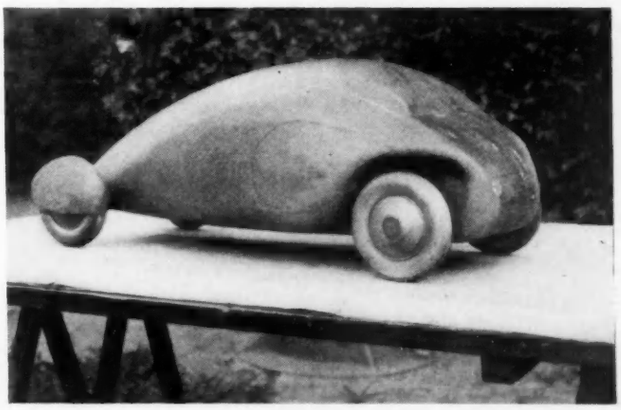


Fig. 13—Model *A* with Modified Front-Wheel Pockets

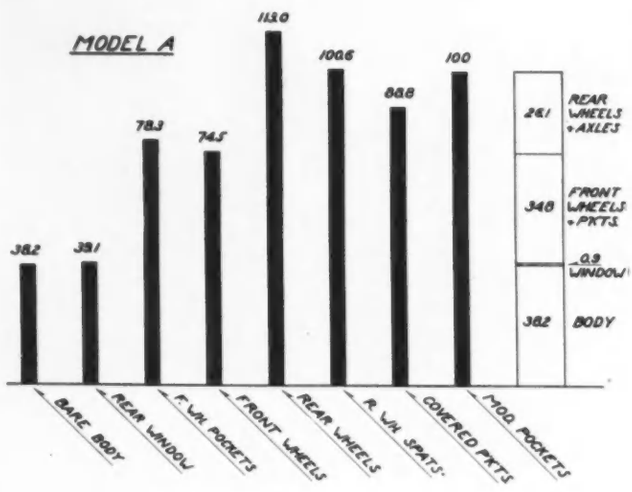


Fig. 14—Drag Analysis—Model *A*

—method and that the latter agreed very well with an extrapolation of the results obtained by various degrees of removal of the boundary layer from a fixed ground plane.

An influence much more important than ground effect is the one known as "horizontal buoyancy." The writer has found no reference to this correction in previous automobile-model work although it is customarily used in connection with airship models. Horizontal buoyancy arises from the fact that the static pressure in the test section of nearly all open-throat (Eiffel-type) wind-tunnels increases with the distance downstream. The variation of fluid pressure over the surface of a solid body gives rise to a force which is directed from the high toward the low-pressure region, in this case an upstream force or negative drag. The results of drag tests made under such conditions are, therefore, erroneous in the optimistic sense until corrections for horizontal buoyancy have been applied. This correction augmented our experimentally determined net drags for the complete models by 15 to 20 per cent.

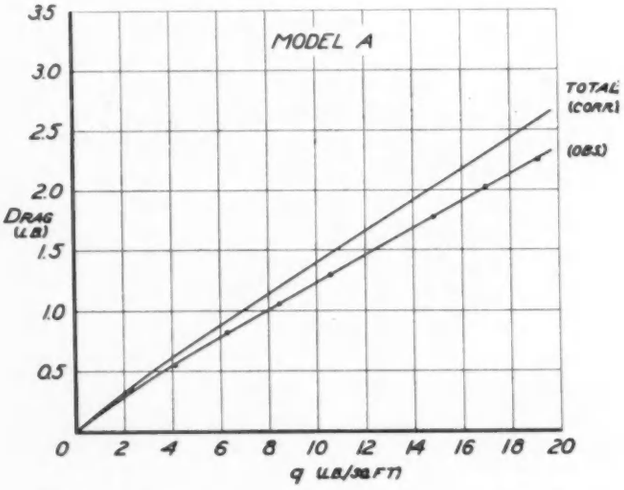


Fig. 15—Total Drag—Observed and Corrected—Model *A*

The tests of Model *A* began with the bare, undeformed body. Subsequent alterations and additions consisted of carving a rear-window recess, forming the wheel pockets, putting front wheels in place, adding rear wheels and axles, enclosing rear wheels in "spats," closing the front wheel-pockets as shown in Fig. 12, and altering the pockets to the form shown in Fig. 13.

Models *B* and *C* were tested under the conditions required for the determination of the contributions of the bare body and both sets of wheels to the total drags. Model *B′* was tested only in the completely assembled condition.

Lifts were measured and horizontal buoyancy corrections were applied only in connection with the tests of the complete models.

Results

An analysis of the total drag of Model *A*, with front wheel-pockets of the form shown in Fig. 13, is presented in Fig. 14. The variation of total drag with dynamic pressure and the magnitude of the buoyancy corrections are illustrated by Fig. 15.

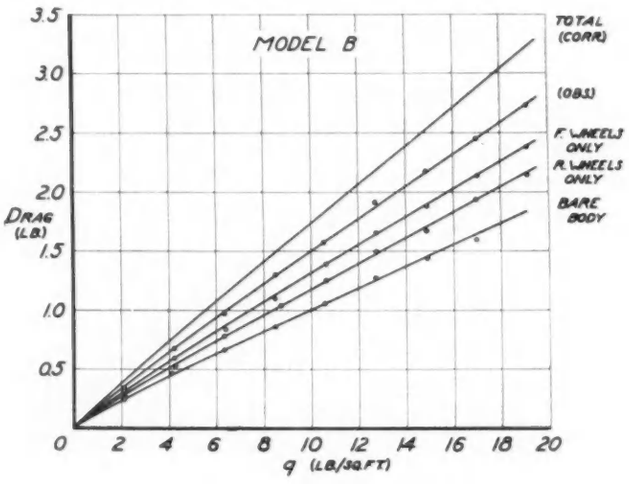


Fig. 16—Drag Analysis— Model *B*

Curves of component, total and corrected drag versus dynamic pressure for Models *B* and *C* are shown in Figs. 16 and 17. The resistance characteristics of Model *B′* are compared with those of Model *B* in Fig. 18. The lift characteristics of all the models are presented in Fig. 19.

Discussion

The drag-coefficient curves for the four models appear in Fig. 20. Although the coefficients are far smaller than that for the conventional type, relatively large differences occur within the group. To deduce the causes of these variations, it will be convenient to follow the evolution of Model *B′* from Model *A*. It is apparent that widening the tail caused the bare-body drag of Model *B* to exceed that of Model *A*. However, the much smaller difference between the corresponding total drags indicates that the enclosure of the rear wheels was sufficiently beneficial to neutralize part of the unfavorable effect of increased width. This development is extended with Model *C*; in this case, the increase of bare-body drag is smaller and the total drag is less than that of Model *A*. Although Model *C* had the smallest drag mea-

sured, the obvious impracticability of its narrow rear tread lead to the concentration of attention upon Model *B*. The latter was therefore modified (to the form *B'*) with the objects of reducing its comparatively large lift and improving the shapes of the rear transverse profiles. The results of these modifications are to be seen in Figs. 18 and 19. It may be of interest to know that a calculation of the reduction of induced drag corresponding to the observed change of lift accounted for only three-fourths of the improvement actually effected.

It will be observed that the drag coefficients of the rear-engine models are approximately one-fourth as large as that corresponding to the conventional type and about one-half as great as that for Lay's final compromise design. If we take the difference between the drag coefficient of the conventional automobile and that of the airship hull as the limit of aerodynamic improvement, then the rear-engine models represent the accomplishment of about 80 per cent of the possible refinement. Confirmation of the previous statement that the drag coefficient of a well-streamlined car should not

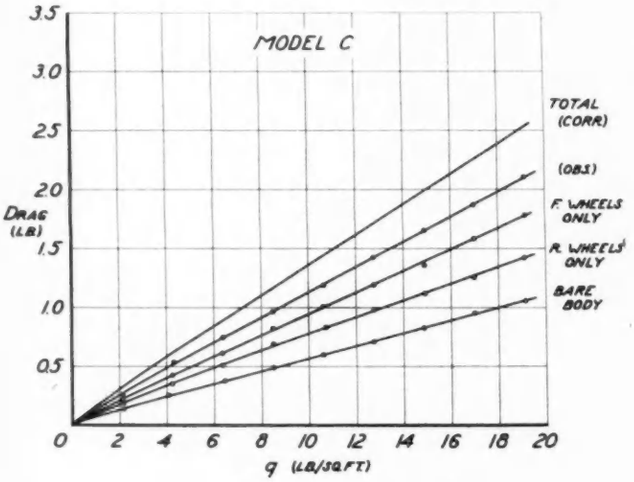


Fig. 17—Drag Analysis—Model *C*

exceed that of an airship hull having a frontal area three times that of the automobile is also given by Fig. 20.

If practical considerations be given any weight at all, Model *B'* is certain to be chosen as the most promising member of the series. The other three are eliminated for the following reasons: Model *C* is ruled out on account of its narrow rear tread; Model *B*, on account of its large drag; and Model *A*, because its slight aerodynamic superiority is insufficient to justify its several impractical features. Before comparing the characteristics of Model *B'* with those of other types, some more detailed remarks upon its properties would seem to be in order.

It is interesting, and somewhat surprising, to see that simplicity of external form, large enclosed volume and great latitude for chassis arrangement can be provided in a body which has an air resistance almost negligibly greater than that of the impractical "airship on wheels" type. Further, if we neglect scale and ground effects, the total lift of a full-size replica of Model *B'* works out to 89 lb. for a speed of 80 m.p.h. and the line of action of the resultant air force is found to intersect the horizontal plane surface defined by the wheel centers at a point about 15 in. forward of the rear-axle line.

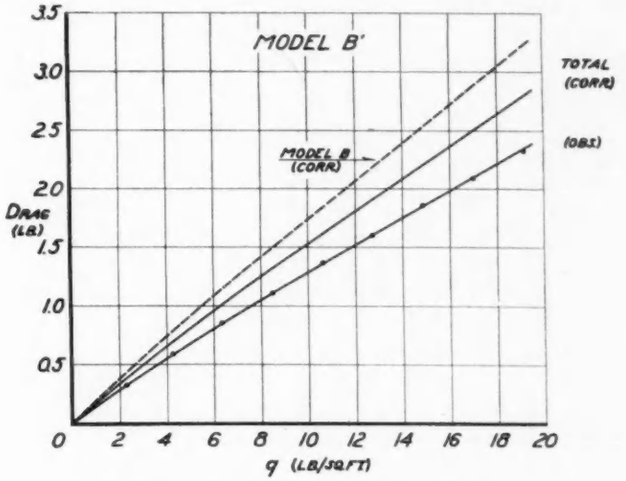


Fig. 18—Total Drag—Models *B* and *B'*

When one compares this force and its point of application with the weight and position of one rear-seat passenger in a conventional sedan, it becomes apparent that no appreciable "floating" tendency or pitching disturbance is to be expected in the proposed type. Finally, lest the bugaboo of induced drag cause alarm, with span replaced by body width in the accepted formula and using the foregoing value of lift, the induced drag is found to be 4.75 lb. at 80 m.p.h.; this requires the expenditure of 1.01 b.hp.

Let us now compare the power requirements of a full-scale replica of Model *B'* with those of other types. All may be assumed to have the same weight and, consequently, the same rolling resistance; these values have been calculated, in accordance with Equation (1), for a weight of 4000 lb. The frontal areas and drag coefficients used in the calculations of air resistance are tabulated as follows:

	Frontal Area (S), Sq. Ft.	C_D	C_DS
Front engine, conventional	28	0.607	17.00
Front engine, compromise (Lay)	30	0.314	9.42
Rear engine, Model *B'*	22	0.164	3.61

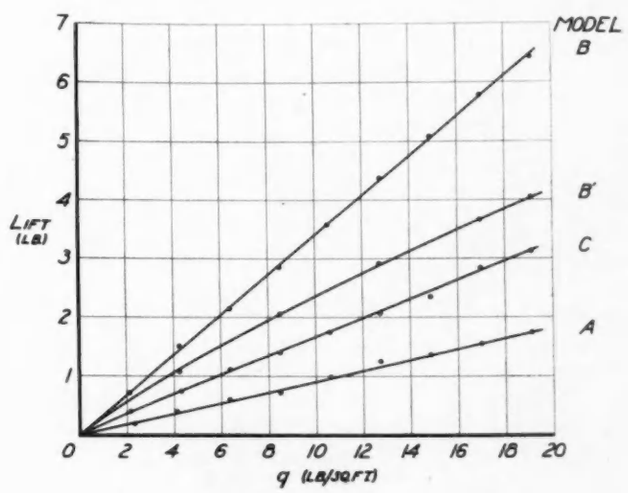


Fig. 19—Lift Characteristics—All Models

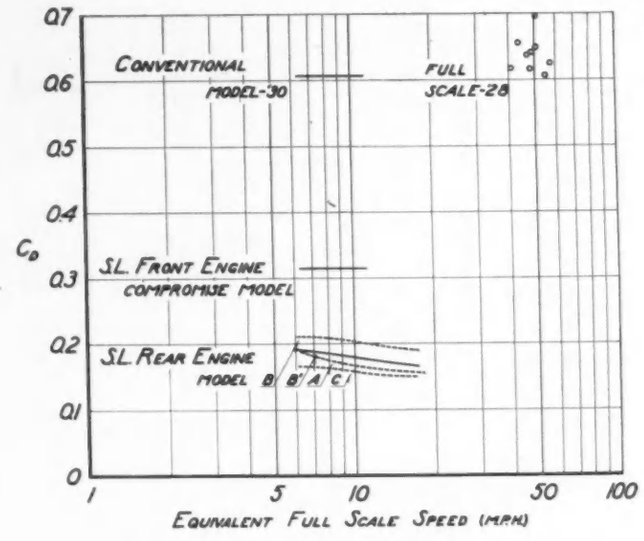


Fig.20—Drag Coefficients of Various Types. (Equivalent Full-Scale Speed = Linear Scale of Model × Wind Speed)

The value of S used for the conventional type is an average of actual measurements of a number of current 5-passenger sedans of approximately 125-in. wheelbase. It is believed that a car patterned after Lay's compromise model would have a slightly greater frontal area than that of the conventional car because the upper part of the body would be wider. The full-scale frontal-area of Model B' was determined by planimetry of the model drawing. At first glance, this value may seem suspiciously small but a satisfactory explanation is not hard to find. The factor of greatest importance is overall height; with no shaft or transmission beneath it, the passenger compartment of the rear-engine rear-drive car can be slung as low as it has been in the case of the front-engine front-drive combination. The average width is also somewhat less than is now conventional as a consequence of the amidship position of the rear seat, the narrow tread (56 in.), and the generous rounding of the roof.

The third column of the preceding tabulation contains values which are directly proportional to the air resistances of the three cars for equal speeds. It will be seen that the air resistance of the conventional car can be reduced by approximately 45 and 79 per cent by the use of streamlined bodies with the front- and rear-engine chassis, respectively. The reductions of total resistance are, naturally, of a smaller order because the rolling resistance is assumed to be unchanged.

The total power requirements of the three cars are illustrated by Fig. 21. Although the curves are widely separated at the higher speeds, it is obvious that the absolute values of the low-speed ordinates differ by small amounts. Such curves as these are largely responsible for the belief that the reduction of air resistance can have little practical value at low speeds, and that the only appreciable benefits to be obtained by streamlining are substantial reductions of the power requirements at high speeds and an increased top speed.

Fig. 22 throws a different light on this question. These relative power curves are based upon the calculated ordinates of the curves of Fig. 20. Here, in final form, we find the verdict on the controversial issue stated in the introduction. It will be seen that required engine power may be reduced by 19, 42 and 55 per cent at speeds of 20, 40 and 60 m.p.h., respectively, by the adoption of a rear-engine streamlined-car. Unless such improvements as these can be properly classified as inconsequential, it is evident that previously accepted ideas of the importance of motor-car air-resistance are erroneous and that revolutionary improvements are to be had by the coordination of aerodynamic and mechanical design.

Before closing this phase of the discussion, it may be of interest to compare the characteristics of Model B' with those of the best model of the front-engine series tested at the University of Michigan[7]. This is Model No. 18; it has been previously mentioned as having a length of 2.6 times its wheelbase. The drag coefficient of No. 18 is 0.121 ($K = 0.000309$). Using 30 sq. ft. as the frontal area for this model, the product C_DS is 3.63 sq. ft. The total and relative power curves for the two cars would, therefore, be practically identical. It is thus shown that a rear-engine car of acceptable dimensions may have aerodynamic characteristics which can be equalled, in the front-engine type, only by the provision of a tail of prohibitive length.

Up to this point, the discussion has been limited, almost entirely, to considerations of aerodynamic characteristics and power requirements and it has been demonstrated that major improvements can be effected without increasing current overall dimensions. However, the project of turning the existing motor car end-for-end entails a formidable list of design problems which are not to be dismissed by a wave of the hand. The writer does not feel competent to present detailed discussion on most of these points and will, therefore, confine himself to a few observations of general nature.

It is expected that the probable difficulties of aerodynamic character such as that of cooling without a nose radiator, ventilation of the passenger compartment, elimination of fumes from the engine, and the like, can be overcome without a great deal of trouble. An adequate V-type engine and its accessories can be housed within the space provided in the proposed arrangement and it seems reasonable to anticipate considerable simplification of the power-transmission system. The question of access to the front seat can certainly be answered satisfactorily. If there are likely to be more serious suspension and steering problems than those of present-day

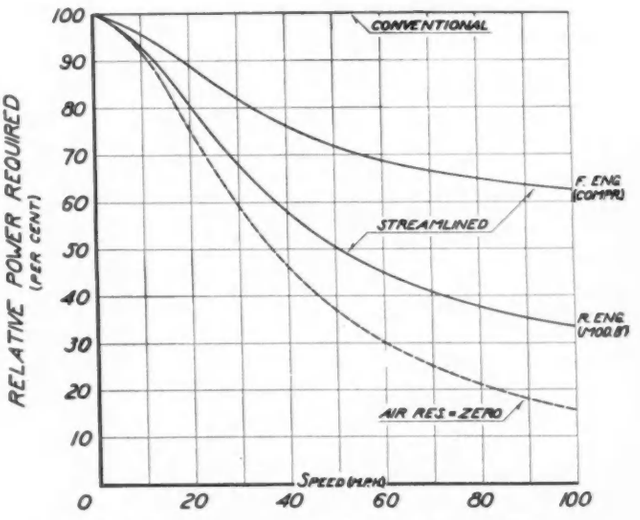


Fig. 21—Power Requirements—Conventional and Streamlined Sedans

[7] See S.A.E. TRANSACTIONS, vol. 28, pp. 144 and 177; Is 50 Miles per Gallon Possible with Correct Streamlining? by W. E. Lay.

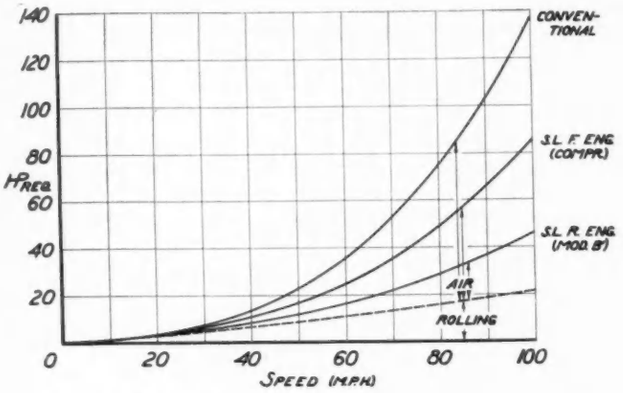


Fig. 22—Relative Power Requirements—Conventional and Streamlined Sedans

conventional design, the writer's ignorance saves him these worries.

As a premium for the solution of these problems, an imposing list of attractive features will be found in a car of the proposed type. The improvements of economy and performance come first and are, probably, of the greatest importance. However, the better and more uniform riding qualities promised by the placing of the variable load close to the center of gravity deserve more than casual mention. The lowering of the center of gravity is likewise desirable and the reduction of the moment of inertia about the vertical centroidal axis should lead to improved handling qualities. Last, but not necessarily least, passenger comfort will surely benefit by the elimination of noise and heat from the engine compartment and the reduction of wind noise which is sure to accompany the smoothing of external contours.

It will be a great surprise to the writer if the design problems which must be solved to secure these advantages prove more than a temporary obstacle to the American engineers who have developed the countless improvements and new devices which distinguish the present motor car from the "contraption" of thirty years ago. It is therefore predicted with some confidence that cars of the proposed type may be expected to appear before long and that we will then be really justified in bidding farewell to the "horseless carriage."

Bibliography

Wind-Tunnel Tests and Body Design, Julio Andrade; S.A.E. JOURNAL, July, 1931, p. 29.

The Development of a Rear-Engined Streamlined Car, Sir Dennistoun Burney; S.A.E. TRANSACTIONS, vol. 27, p. 57.

The Tear-Drop Car, W. T. Fishleigh; S.A.E. JOURNAL, November, 1931, p. 353.

Aerodynamic Characteristics of Automobile Models, R. H. Heald; *Journal of Research,* National Bureau of Standards, August, 1933.

Wind Resistance versus Car Performance, Louis Schwitzer; S.A.E. JOURNAL, June, 1931, p. 631.

Economy of Streamlining the Automobile, O. G. Tietjens; S.A.E. TRANSACTIONS, vol. 27, p. 150.

Discussion of Reid Paper

Ground Effect and Horizontal Buoyancy Commented Upon

—Dr. Wolfgang Klemperer
Cuyahoga Falls, Ohio

THERE are two places in the paper where experimental technique of other investigators may seem to be criticized. Professor Reid's statements themselves do not imply such generalizations; but it may be in order to mention that, if the omission of a simulation of ground effect may have been justified in the case of these models, this is of course no proof that the same would be true of other models which give more lift, and might not be short, flat and smooth underneath with well-rounded approach and ample ground-clearance.

The horizontal buoyancy effect mentioned is of course peculiar to each tunnel and to the location of the model in it. The 15 to 20-per cent influence found is unusually large and it must not be concluded that all other tests are that much in error. In fact, in some tunnels this error is of opposite sign, and in some other experiments it was ascertained to be negligible.

Opinions Concerning Parameter, Drag Coefficient and Stability

—T. Edward Moodie
Georgia School of Technology

IN the writer's opinion frontal area is a poor parameter to use for comparison of drag. The use of frontal area as a fundamental parameter in aeronautical work was discontinued several years ago except for a few special applications. It would seem to be much better to use equivalent flat-plate parasite-area or simply drag area; that is, an hypothetical area the drag coefficient of which is 1.0. Unless these or similar parameters are used, it will be impossible to compare correctly and easily the relative degree of streamlining of cars of different sizes and shapes.

After all, the problem is to transport two or more passengers with a minimum resistance. Reducing the drag coefficient while at the same time increasing the frontal area may not result in any material advantages. Professor Reid's statement that the rear-engined type is clearly indicated is in my opinion entirely too definite a conclusion to draw from the facts at hand. No doubt the front engine-location pre-

sents certain obstacles to proper streamlining. But to say that streamlining cannot be effectively accomplished without moving the engine to the rear is entirely unwarranted. It might be said that in a conventional four-wheeled car which is steered by deflecting the front wheels and in which the engine is high, narrow, and long rather than short, low and broad, that proper streamlining with the engine in front cannot be successfully accomplished. But there is no fundamental reason other than custom that causes cars to be built in this manner. It is hard to see why it should be assumed that a rear-engine location is a solution of all our difficulties. Such an assumption ignores cooling problems, the increased danger in a crash and, worst of all, the instability about the yawing axis resulting from the rearwardly located center of gravity.

The writer has tested a front-engined streamlined-car in the wind tunnel and on the road. This car was only 14 ft. 7 in. long and had a drag coefficient, as determined in the tunnel, of 0.169. A refined model only 15 ft. 5 in. long had a drag coefficient (C_D) of 0.135 as determined in the tunnel, which is considerably less than the value of 0.164 referred to in the paper. The full-scale machine actually has been driven over 1100 miles and, from this test alone, it would seem to indicate that a high degree of streamlining can be effected without moving the engine to the rear.

It seems unfortunate that, in such an able piece of research as this paper presents, the question of stability of the car about the yawing axis should be ignored, especially in view of the fact that the conventional style of motor car is not fundamentally stable about its yawing axis and streamlining such a car and then moving the engine to the rear will most certainly make a bad condition worse. This fact is well illustrated by the behavior of the so-called Dymaxian rear-engined car which turned over during a run, probably as a result of instability about its yawing axis. The only other rear-engined car with which I am familiar is Sir Dennistoun Burney's car, which is considerably longer than the average standard car. I do not wish to discount the remarkable advantages to be obtained from proper streamlining, but I do contend that an investigation of drag effects only is not sufficient.

In the study of high-speed motor-cars it is essential in addition to investigate stability about both the yawing and pitching axes as well as controllability about these axes and the effects of side winds before recommending radical changes which will offer only an improvement in drag characteristics. The author has ignored the real difficulties of the rear-engine location; namely, the added danger in a crash due to the soft nose and the fact that the directional instability which is already large in the conventional automobile will be made much worse by the rearward movement of the center of gravity in a rear-engined car.

Mr. Moodie points out the fallacy of basing drag comparisons of different types upon the values of their drag coefficients, alone, and suggests the use of an hypothetical or equivalent frontal area of unit-resistance coefficient as a logical yardstick. It was assumed, perhaps unwisely, that mention of this fact in the text would have been superfluous; the comparisons made there have as their bases the values of the product C_DS. It is regretted that Mr. Moodie cites the results of his own work only in the form which he condemns. He also objects to the selection of the rear-engine type as the one best suited to the attainment of low air-resistance. Without an explanation of some practicable method for reducing the air resistance of a body having a blunt tail, this objection appears to find no support in known facts.

The probable stability and controllability of the streamlined, rear-engine car when operating in cross winds appear to have caused great alarm. Many critics, including Mr. Moodie, have cited the Dymaxion accident in justifying their fears. The similarity between a three-wheel front-drive vehicle and a four-wheel rear-drive car seems, to the writer, somewhat scant to justify the prediction of the latter's char acteristics from those of the former. In general, it is thought that the dangers of directional instability in the proposed type have been greatly exaggerated.

As Mr. Moodie points out, and as anyone can prove for himself by simple road tests, the conventional car will yaw away from the resultant wind rather than heading up into it unless steering corrections are made. In a car of the proposed type, the lateral center of pressure will probably be farther forward and the center of gravity farther aft than those of the conventional car. If equal lateral forces be assumed, then the streamlined rear-engine car will experience the greater yawing moment. However, it is reasonable to expect the streamlined car to experience relatively small lateral forces if its transverse contours are well rounded. For this reason, the writer believes that the dangers of directional instability have been exaggerated. It is planned to do experimental work on this problem at Stanford University.

The oral discussion of this paper brought out conflicting views regarding the effects of style changes upon sales resistance. It is the writer's opinion that it is both illogical and not justified by experience to predict unsurmountable resistance to departures in style when such innovations are necessary for the realization of important practical improvements. Even though the new forms be contrary to current esthetic notions, they appear to gain permanence and to alter public opinion when their practical value is readily demonstrable.

A few outstanding examples are the universal adoption of the ("clumsy, Rube Goldberg, doughnut") balloon tires, the disappearance of the touring car in favor of the ("showcase, death-trap, effeminate") sedan and the current acceptance of the ("nose-heavy, hippopotamus, cow-catcher") form of front-end silhouette necessitated by the new forward engine-locations. While it would be ridiculous to argue that only the practically useful style changes meet with success, it is held that ultimate acceptance of innovations required for the realization of important improvements is almost certain, whereas departures which appeal to taste alone are the ones whose fates hang in the fickle balance of public opinion. When viewed in this light, the potentialities of low-resistance bodies are so great that the writer finds himself in complete agreement with those contributors to the oral discussion who expressed surprise at the apparent reluctance of manufacturers to do any serious work in this field.

Professor Reid's Reply to Comments on His Paper

—Elliott G. Reid
Stanford University

DR. KLEMPERER'S comments form a valuable addition to the text of this paper. It was not the author's intention to imply that ground effect might be ignored in all automobile-model testing or that horizontal buoyancy always has as great importance as in the tests described above.

Cylinder Events Studied in the Logarithmic Diagram

By Alfred T. Gregory, M.E., Dr.-Ing.
Wright Aeronautical Corp.

THE logarithmic diagram lends itself peculiarly to the study of cylinder conditions and to the quick determination of the changes taking place. Although some use has been made of the logarithmic diagram for indicator-card analysis, its use has been rather limited. Much more can be learned by this means than is usually done.

Not only can valve and combustion events be determined; cylinder temperatures can also be found. It will be shown that the cylinder temperatures can be found directly by measurement in the logarithmic diagram, thus obviating any necessity for calculating them.

Curves of internal energy versus temperature make it possible to find the internal energy of the charge at any point, once the temperature is known. It is therefore a relatively simple matter to follow the flow of energy throughout the cycle. A complete picture of the events taking place in the cylinder can thereby be obtained, affording a ready means of studying engine performance.

Examples are given showing the application of the logarithmic method of analysis to several different kinds of indicator cards. These examples indicate that practically any type of indicator card can be analyzed completely in a short time by means of the logarithmic diagram.

VARIOUS methods have been used for determining actual cylinder conditions in an internal-combustion engine from the indicator diagram and for analyzing the changes taking place throughout the cycle. Although much has been learned regarding the events within the cylinder, there is still a great deal to be learned. Means are required whereby a quick and easy analysis of what goes on in the cylinder can be made with a reasonable degree of accuracy so that large numbers of indicator cards can be studied in a short time. It would then be possible to determine the effects of innumerable variables on the combustion and, hence, on engine performance.

Certain properties of the logarithmic diagram make that type of diagram particularly suitable to the study of cylinder events and to the quick determination of conditions within the cylinder. Some advantage has been taken of this fact. However, the diagram is adaptable to making many more determinations than those for which it is usually used. Results are obtained quickly and with reasonable accuracy.

The logarithmic diagram derives its advantage for the study of indicator cards from the nature of its polytropic lines. Any isobaric, isometric, isothermal, adiabatic or other polytropic curve when plotted in logarithmic coordinates of the pressure and volume is a straight line. This fact follows from the logarithmic form of the polytropic equation PV^n = a constant, which is:

$$\log. P + n \cdot \log. V = C \qquad (1)$$

in which P is the pressure, V the volume, n the polytropic exponent and C a constant. The slope of the line, which gives the value of the exponent n, indicates the nature of the change occurring in the cylinder.

The indicator card when plotted in logarithmic coordinates may not be composed actually of straight lines. The compression and expansion lines or portions of them, however, are usually substantially straight.

Resolving the diagram into straight lines makes possible the determination of the exponent n, which represents the average value for a number of points. A more accurate determination of the value of n can be made by this means than by finding the exponent at an individual point, since the method is less subject to errors in the card or to errors in

[This paper was presented at the Annual Meeting of the Society, Detroit, Jan. 16, 1935.]

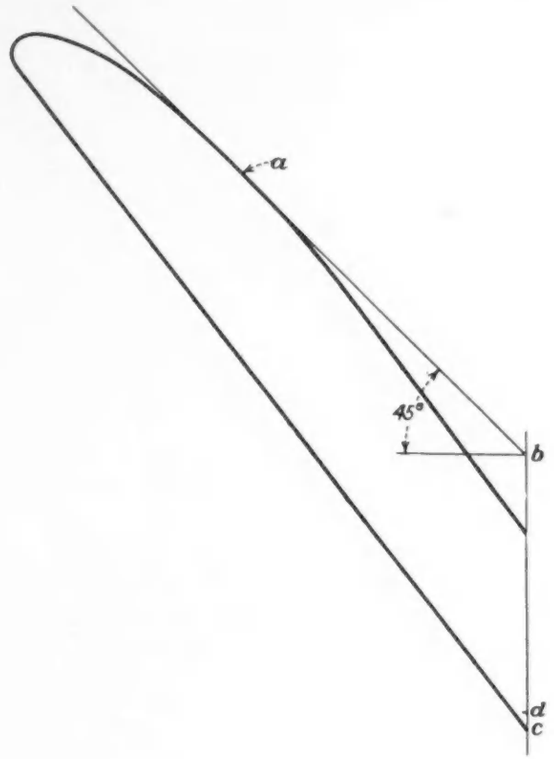


Fig. 1—Logarithmic Diagram of a Hill Four-Cycle Diesel-Engine Operating at 800 R.P.M.

making the determination. Deviations in the curve from the polytropic are readily seen, thus facilitating the determination of the value and combustion events.

Cylinder Temperatures

Since for an isothermal expansion $n = 1$, the slope of the isothermal line, as will be seen from Equation (1), is 1 which is the tangent of 45 deg. Thus, constant-temperature lines in the logarithmic diagram are 45-deg. lines and therefore can be drawn readily with the aid of a 45-deg. triangle. Obviously, the upper line of a number of isothermal lines in any diagram represents the highest temperature.

These facts make the determination of the point of maximum cylinder temperature a very simple process. Once the indicator card has been plotted in logarithmic coordinates, it is necessary only to draw a 45-deg. line tangent to the expansion line. The point of tangency will be the point of maximum cylinder temperature, since no other isothermal could be drawn above it and still touch a point on the curve.

Fig. 1 shows the logarithmic diagram of a Hill four-cycle Diesel-engine operating at 800 r.p.m. The isothermal line *ab* has been drawn tangent to the curve at the point *a*, which is, therefore, the point of maximum cylinder temperature.

This temperature can be determined if the temperature of any other point in the cycle be known. For, along any constant-volume line, which in logarithmic coordinates is a straight vertical line, the ratio of the absolute temperatures is equal to the ratio of the absolute pressures.

It is necessary, therefore, simply to extend the maximum-temperature isothermal-line to a point vertically above the point of known temperature and to determine the ratio of the pressures at those two points. If combustion occurred between the point of known temperature and the maximum-temperature point, the calculated temperature would have to be multiplied by a factor allowing for the increase in volume due to the change in the composition of the charge. Expressed mathematically:

$$aT_2 = T_1 \cdot \frac{p_2}{p_1} \qquad (2)$$

where T is the temperature, p the pressure and a the factor for the change in composition. The index 1 refers to the point at which the temperature is known, and 2 to the point in which it is desired to know the temperature.

The logarithmic form of Equation (2) is:

$$\log. T_2 - \log. T_1 = -\log.a + \log.p_2 - \log.p_1 \qquad (3)$$

Since the sums and differences of logarithms represent distances to be added or subtracted on the logarithmic diagram, this equation shows that it is not necessary to calculate the temperature T_2, but rather that T_2 can be measured.

Thus, the correction for change in the composition of the charge is made by stepping off the distance—log. *a* from the point of known temperature. The value of *a* depends on the amount of the increase in volume accompanying combustion, which, in turn, is dependent on the air/fuel ratio and on the percentage of fuel burned. The corrected point so obtained represents the temperature T_1 for the charge having the same composition as that existing in the cylinder at the time maximum temperature is reached. The term ($\log.p_2$—$\log.p_1$) which is the distance from the corrected point to the maximum temperature isothermal is then equal to ($\log.T_2$—$\log.T_1$).

In Fig. 1 the temperature in point *c* was known to be 620 deg. fahr. absolute. The distance from *c* to *d* was made equal to—log.*a* where *a* is 0.90. The distance *db* is equal to ($\log.p_2$—$\log.p_1$) in which p_2 is the pressure at the point *b* and p_1 the pressure at the point *d*. As pointed out above, however, the distance *db* also equals ($\log.T_2$—$\log.T_1$), T_2 being the temperature in *b* and T_1 the temperature in *d*. If a logarithmic scale be used to measure the distance *db*, placing the value T_1 at the point *d*, the temperature T_2 can be read directly on the scale at the point *b*. The maximum temperature in this diagram was thus found to be 2700 deg. fahr. absolute.

The above procedure suggests a method for measuring the cylinder temperatures throughout the cycle. By drawing a convenient 45-deg. isothermal-axis representing a known temperature, the ratio of the temperature at any point in the cycle to the known temperature would be represented by the distance from the point to the isothermal axis, the distance being measured along a constant-volume line. The desired temperature could therefore be measured by means of a logarithmic scale as outlined above, placing the value of the known temperature at the intersection with the isothermal axis. The temperatures throughout the entire cycle can thus be measured, simply by sliding the logarithmic scale along the isothermal axis.

Actually, two isothermal axes would be required, one for the compression line and one for the expansion line, to allow for the increase in volume accompanying combustion. The amount of the volume increase varies with the air/fuel ratio as is illustrated[1] in Fig. 2. The curve in Fig. 2 shows the volume after combustion, the volume before combustion being 1.00, and therefore gives the value of $1/a$. Knowing the

[1] See Automobile and Aircraft Engines; Judge.

air/fuel ratio, the increase in volume can be found by reference to this curve and thus the distance —log.*a* determined. As a fair approximation, however, the curve indicates that 5 per cent may be taken as the percentage increase in the volume over a considerable range of the air/fuel ratio.

During the actual period of combustion, the amount of correction varies with the quantity of fuel burned. The correction may, however, be considered proportional to the weight of the fuel burned, thus making the upper isothermal axis bend slightly downward at the combustion end of the stroke to meet the lower axis in the ignition point. The weight of fuel burned may be taken proportional to the pressure rise or to the increase in volume.

Probably the most convenient temperature to use for the isothermal axis is $T = 1000$ deg. absolute. This value would facilitate the use of a logarithmic scale in reading off the temperatures. The axis may be located, once the suction temperature is known, by laying off (log.1000—log.T_s) from the point of closing of the inlet valve, T_s being the suction temperature.

The suction temperature can be found after making proper allowance for the heating and cooling effects on the charge. The fresh charge is first cooled by the evaporation of the fuel in the gasoline engine. On entering the cylinder the charge is heated by direct contact with the intake valve and cylinder walls. Further heating occurs when the charge becomes mixed with the residual gases in the cylinder. Examples illustrating the method of calculating the suction temperature are given below.

Internal Energy

Knowing the temperature in the cylinder, it is possible to ascertain the internal energy of the charge also. Any determination of the internal energy of the mixture of fuel and air or of the combustion gases must take into account, however, the change in specific heat with change in temperature and the dissociation of the products of combustion at high temperatures. The specific heat of the constituent gases has been found for any temperature over a large temperature range by direct experiment. The amount of energy taken up by the gases as sensible heat can therefore be readily calculated.

The degree of dissociation is influenced by variations in the pressure and by the relative proportions of the gases present. The energy absorbed in this manner can not be readily calculated. From the work done by Tizard and Pye, however, Ricardo[2] has constructed a curve, shown in Fig. 3, which gives the total internal energy of the mixture at any temperature.

[2] See The High-Speed Internal-Combustion Engine; H. R. Ricardo.

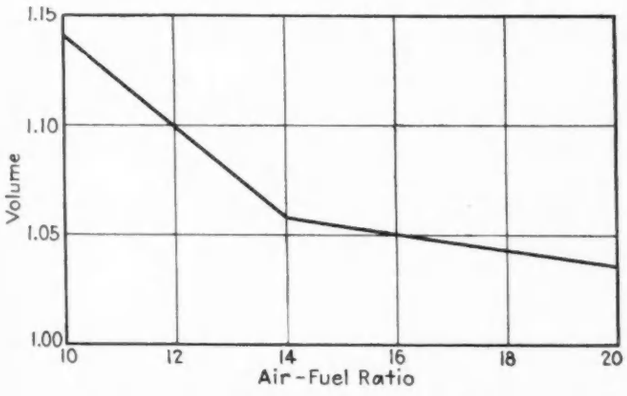


Fig. 2—Illustrating How the Amount of the Volume Increase Varies with the Air/Fuel Ratio

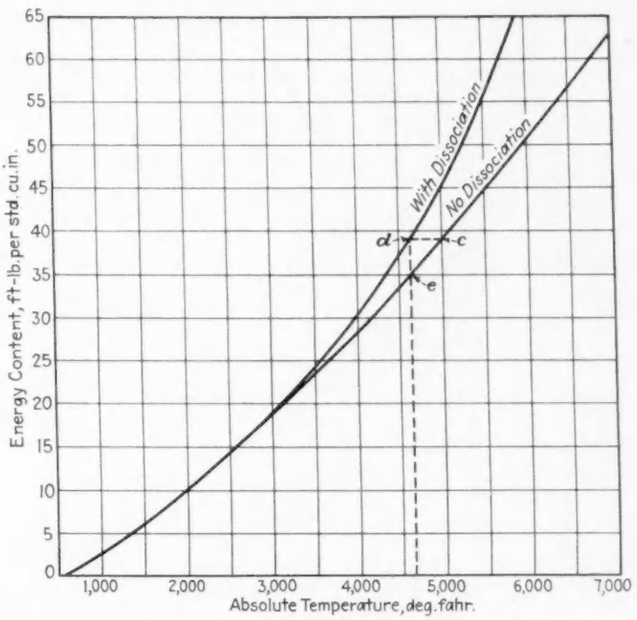


Fig. 3—Curves Showing Both the Total Internal Energy of the Charge with Dissociation and the Sensible Heat of the Charge

The curves in Fig. 3 show both the total internal energy of the charge with dissociation and the sensible heat of the charge. While the curves represent a theoretically correct mixture of fuel and air, the use of somewhat leaner or richer mixtures does not affect the values shown appreciably.

The heat units are given in foot-pounds per standard cubic inch, since this unit gives small convenient numbers with which to work and since the work done can be compared readily with changes in the internal energy. Temperatures are given in degrees fahrenheit absolute, since the temperatures measured in the logarithmic diagram are absolute temperatures. Zero energy is taken at 672 deg. absolute (212 deg. fahr.).

The internal energy of the charge can be determined by reference to these curves, once the temperature in the cylinder is known. It is possible also to determine the energy of dissociation and to allow for the effect of dissociation when measuring the cylinder temperatures in the logarithmic diagram.

Suppose the temperature as measured to have been 5000 deg. With no dissociation, the energy of the charge would be given by the point *c* on the curve of sensible heat in Fig. 3. This energy—39.4 ft-lb. per std. cu. in.—would then correspond to the total energy of the charge.

But if dissociation occurred and the same amount of energy were put into the charge, the total internal energy would be represented by the point *d* on the curve of total internal energy. The actual temperature would then be less than 5000 deg. by the amount *cd* or 420 deg. Thus the actual temperature with dissociation would be 4580 deg. The energy absorbed by the dissociated products is given by *de* and amounts to 4.2 ft-lb. per std. cu. in. in this instance.

Analysis of Indicator Cards

The knowledge of the temperatures and internal energies throughout the cycle makes possible the complete study of the

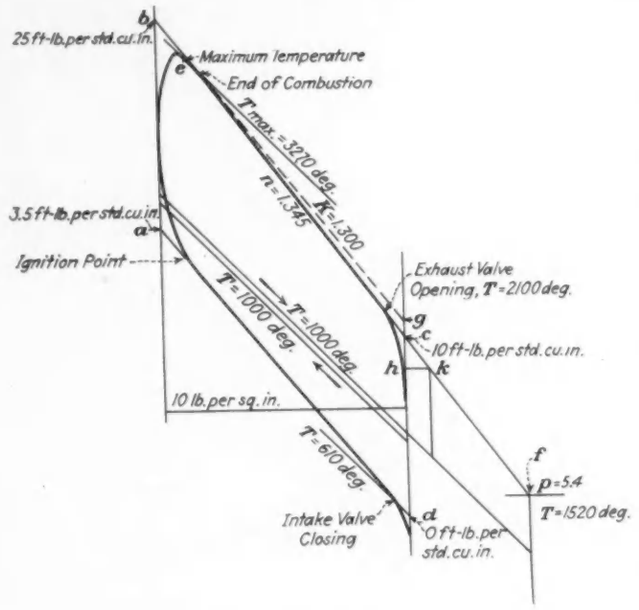


Fig. 4—An Indicator Card of an Hispano-Suiza Engine Running at 1200 R.P.M. at an Altitude of 25,000 Ft.

events taking place within the cylinder. In conducting this study of the indicator card an ideal cycle has been set up approximating closely the actual card. This procedure greatly facilitated the analysis and gave results that appear reasonable.

Fig. 4 shows an indicator card of an Hispano-Suiza engine running at 1200 r.p.m. at an altitude of 25,000 ft., which has been plotted in logarithmic coordinates[3]. The valve and combustion events are readily seen as the points of departure of the curve from the polytropic compression and expansion lines.

Obviously, during the time the valves are open, no polytropic change could take place in the cylinder. On the other hand, while the valves are closed the changes which take place in the cylinder, barring combustion, are not sudden but gradual changes and, therefore, are not apt to cause sudden deviations from the polytropic curve. Accordingly, the polytropic portions of the compression and expansion lines represent only the times when the valves are closed.

The point of closing of the intake valve is therefore the point in which the curve first touches the polytropic compression line. The point of opening of the exhaust valve is similarly the point in which the curve first leaves the polytropic expansion line.

Since the combustion is accompanied by a rapid temperature rise, the beginning of the combustion is marked by the point in which the curve suddenly leaves the polytropic compression line. As the combustion is finished there is a sudden ceasing of the temperature rise and an actual falling off in temperature. From this point on the expansion becomes polytropic. Thus, the end of the combustion is given by the point in which the curve joins the polytropic expansion line.

The first step in the analysis of the card was to estimate the suction temperature, which was done as follows:

[3] See Pennsylvania State College Engineering Experiment Station Bulletin No. 35; The Tangent Method of Analysis of Indicator Cards, by Schweitzer.

[4] See The High-Speed Internal-Combustion Engine; H. R. Ricardo.

Pressure of residual gases at end of exhaust stroke (taken from indicator card), lb. per sq. in., 5.4.

Volume of residual gases (in terms of compression ratio), 1.

Temperature of residual gases (assumed), deg. fahr. absolute, 1200.

Volume of residual gases at standard temperature and pressure, 0.15.

Pressure of fresh charge at closing of intake valve (taken from indicator card), lb. per sq. in., 5.4.

Volume of fresh charge at closing of intake valve (in terms of compression ratio), 3.89.

Temperature of air outside the cylinder (measured), deg. fahr. absolute, 470.

Temperature rise due to contact with walls and intake valve (assumed), deg. fahr., 100.

Temperature drop due to evaporation of fuel (assumed), deg. fahr., 40.

Temperature of fresh charge inside the cylinder, deg. fahr. absolute, 530.

Volume of fresh charge at standard temperature and pressure, 1.32.

Total volume of residual gases and fresh charge at standard temperature and pressure, 1.47.

Suction temperature—$\frac{4.89}{1.47} \cdot \frac{5.4}{14.7} \cdot 492$—deg. fahr. absolute, 600.

In this computation 4.89 is the total cylinder volume at the point of closing of the intake valve while 1.47 is the total volume of residual gases and fresh charge in the cylinder at standard temperature and pressure. The pressure in the cylinder at the point of closing of the intake valve is 5.4. The standard pressure is 14.7 and the standard temperature 492 deg. fahr. absolute.

The temperature of the residual gases can easily be measured in the logarithmic diagram once the isothermal axis has been drawn. In estimating the suction temperature the residual-gas temperature is first assumed and then checked by measurement. If the measured value does not agree with the assumed temperature, a recalculation may be necessary.

The temperature drop due to the evaporation of the fuel was taken as 40 deg. for the case of complete evaporation.

The temperature rise attributed to the transfer of heat to the charge from the cylinder walls and intake valve during the suction stroke was assumed from figures given by Ricardo[4], who estimated the temperature rise from this cause from actual engine-test data and found it to be between 95 deg. and 155 deg. With the low operating conditions of this test, the heat absorbed was taken to be relatively small.

The isothermal axis for compression was drawn first by laying off the distance (log.1000—log.600) above the point of closing of the inlet valve. The volume increase during combustion was taken to be 6 per cent so that the isothermal axis for expansion was drawn a distance —log.0.933 or +log.1.06 above the axis for compression.

In order to check the assumption of 1200 deg. as the temperature of the residual gases, the expansion line in Fig. 4 was extended to the point *f*, in which point the pressure of the charge was 5.4 lb. per sq. in. and the volume 14.1 cu. in. Likewise, the isothermal axis for expansion was extended to the volume 14.1 cu. in. The temperature of the residual gases was then read on the scale at the point *f* and found to be 1500 deg.

In making this determination of the temperature of the residual gases it is assumed that the expansion of the cylinder

charge on down to the pressure of the residual gases continues along the same polytropic curve as the portion of the expansion previous to the opening of the exhaust valve. Since the portion of the charge remaining within the cylinder is subjected to the same temperature conditions as before the valve opening, this assumption appears reasonable.

Recalculating the suction temperature using 1500 deg. as the temperature of the residual gases instead of 1200 deg. resulted in raising the suction temperature to 610 deg. The isothermal axes were then redrawn and the temperature of the residual gases measured again and found to be 1520 deg.

The suction temperature so estimated is probably within about 5 per cent of the correct value. Consequently, the temperatures measured in the diagram will also be accurate to within about 5 per cent.

The maximum temperature isothermal was drawn tangent to the expansion line at the point *e*. Measurement shows this temperature to have been 3300 deg. Some dissociation occurred, however, so that the actual temperature was about 30 deg. lower, thus giving 3270 deg. as the maximum temperature of the cycle.

Should it be desired to find the temperature at any point after the exhaust valve has opened, such as the point *h*, this temperature can be found in a manner similar to that of finding the temperature of the residual gases. It is simply necessary to draw a constant-pressure line through *h* intersecting the adiabatic line *bf* in the point *k*. The temperature at *k* which can be measured will be the temperature at the point *h*.

Temperatures in the cylinder throughout the exhaust stroke can be found by this method. The mean cylinder temperature at any point in the suction stroke can be found by making a similar calculation to that for determining the suction temperature.

The heat input to the charge, neglecting losses, was determined to be 21.5 ft-lb. per std. cu. in. by taking the difference in the internal energies at the points *a* and *b*.

The combustion efficiency may be defined as the ratio of the heat actually supplied to the charge to the heat contained in the fuel supplied to the charge. If the combustion efficiency be taken to be 65 per cent in this instance, the actual heat supplied in the fuel was 33.1 ft-lb. per std. cu. in.

Similarly, the sensible heat still contained in the combustion gases at the end of the expansion stroke was found by taking the drop in the internal energy of the charge between the points *c* and *d*. This heat was found to be 10 ft-lb. per std. cu. in. or 30.2 per cent of the heat input in the fuel.

The work done on the piston is given by the equation:

$$W = \frac{P_1V_1 - P_2V_2}{n - 1} \qquad (4)$$

where W is the work done, P is the pressure of the charge, V the cylinder volume and n the exponent for the curve between the points indicated by the indices 1 and 2.

The work done during the expansion stroke was computed as follows:

$$W = \frac{P_bV_b - P_cV_c}{n - 1}$$

$$= \frac{170 \cdot 1 - 16.8 \cdot 5.6}{1.345 - 1} \cdot \frac{1}{12} \cdot \frac{1}{1.47}$$

$$= 12.4 \text{ ft-lb. per std. cu. in.}$$

In this computation the cylinder volume in cubic inches has been expressed in terms of the compression ratio. Dividing by 12 converts the units obtained from inch-pounds into foot-pounds. The term 1.47 is the number of standard cubic inches of charge in the cylinder in terms of the compression ratio.

The drop in the internal energy of the charge during the expansion stroke is given by the difference in the internal energies at the points *b* and *c* and was found to be 15 ft-lb. per std. cu. in.

The heat loss to the cylinder walls during the expansion stroke is the difference between the drop in the internal energy and the actual work done on the piston. This loss amounted to 2.6 ft-lb. per std. cu. in., which is 7.9 per cent of the heat input in the fuel.

This seemingly rather small amount of heat absorbed by the cylinder walls during the expansion stroke points to the probability that most of the heat lost in this way is transferred to the walls and exhaust valve during the exhaust stroke. The fact that the combustion gases are still at a very high temperature at the end of the expansion stroke and that they flow past the walls of the exhaust port and the face of the exhaust valve at a high velocity quite possibly accounts for one-half or more of the heat lost to the cylinder walls.

Had there been no heat loss to the cylinder walls during the stroke, the expansion would have been adiabatic as shown by the dash line *cg*. This adiabatic line, which has an exponent of 1.300, was found by determining the polytropic line starting from the point *b* for which the drop in the internal energy of the charge was equal to the work done on the piston.

For the expansion at 1.300 the drop in the internal energy and the work done would each be 12.6 ft-lb. per std. cu. in. Since the work done with heat loss to the cylinder walls was 12.4 ft-lb. per std. cu. in., the gain in power by the elimination of this loss is 0.2 ft-lb. per std. cu. in. or only 2.1 per cent of the power output of the engine. At the same time the heat contained in the exhaust would be increased by 2.4 ft-lb. per std. cu. in. or an increase from 30.2 per cent to 37.4 per cent of the heat in the fuel.

Supercharged Engine Card

Fig. 5 shows the analysis of a diagram taken on a supercharged Cyclone engine operating at 2000 r.p.m. with 39.24 in. Hg. absolute manifold pressure.

The suction temperature was calculated as follows:

Volume of residual gases in the cylinder at end of exhaust stroke (in terms of compression ratio), 1.

Temperature of residual gases (checked), deg. fahr. absolute, 2900.

Pressure of residual gases (from indicator card), lb. per sq. in., 14.7.

Volume of residual gases at standard temperature and pressure, 0.17.

Temperature of fresh charge in intake manifold (measured), deg. fahr. absolute, 590.

Temperature rise due to contact with valve and cylinder walls (assumed), deg. fahr., 150.

Temperature of fresh charge in cylinder before mixing with residual gases, deg. fahr. absolute, 740.

Pressure in cylinder at end of suction stroke, lb. per sq. in., 17.5.

Volume of fresh charge,

$$\left[5.4 + \left(\frac{17.5 - 14.7}{17.5}\right)\right], \ 5.56.$$

In this calculation of the volume, 5.4 is the displacement of the piston; 17.5 is the pressure at the end of the suction stroke and 14.7 the pressure of the residual gases at the beginning of the suction stroke. This computation allows for the com-

pression of the residual gases by the incoming fresh charge.

Volume of fresh charge at standard temperature and pressure, 4.40.

Total volume of fresh charge and residual gases at standard temperature and pressure, 4.57.

Suction Temperature—$\frac{6.40}{4.57} \cdot \frac{17.5}{14.7} \cdot 492$—deg. fahr. absolute, 820.

In this computation 6.40 is the total cylinder volume at the end of the suction stroke; 4.57 is the total volume of residual gases and fresh charge in the cylinder at standard temperature and pressure. The pressure at the end of the suction stroke is 17.5 while the standard temperature and pressure are 492 and 14.7 respectively.

In the above calculation of the suction temperature no allowance was made for temperature drop due to evaporation of the fuel. It was assumed that all the fuel had evaporated by the time it left the supercharger.

Inasmuch as the air/fuel ratio was approximately 12/1, the volume increase was taken as 8 per cent.

The following determinations were made from the diagram:

Maximum cylinder temperature (as measured in the diagram), deg. fahr. absolute, 6200.

Maximum cylinder temperature (corrected for dissociation), deg. fahr. absolute, 5400.

Temperature at end of expansion stroke (corrected for dissociation), deg. fahr. absolute, 4100.

Heat input to charge (neglecting losses), ft-lb. per std. cu. in., 54.5.

Heat supplied in fuel, ft-lb. per std. cu. in., 85.7.

Combustion efficiency, per cent, 63.6.

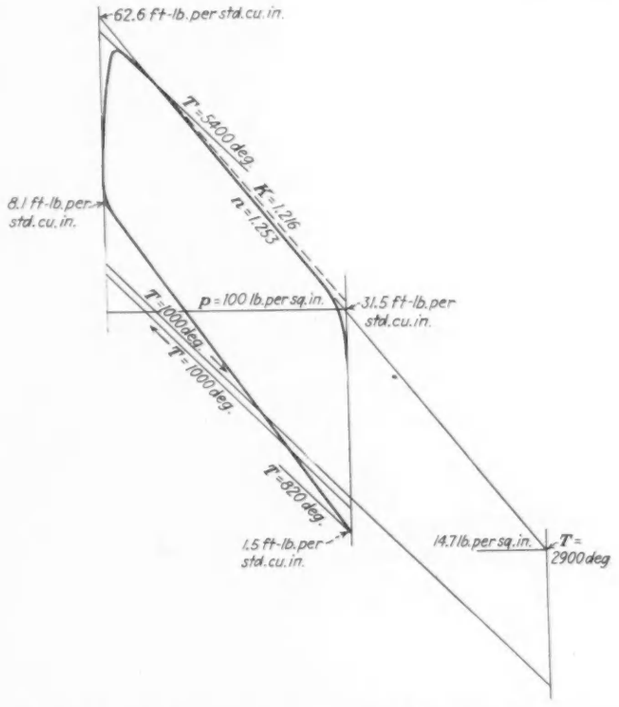


Fig. 5—Analysis of a Diagram Taken on a Supercharged Cyclone Engine Operating at 2000 R.P.M. with an Absolute Manifold Pressure of 39.24 In. of Mercury

Heat supplied in combustion gases at end of expansion stroke, per cent, 35.

Heat supplied which was lost to cylinder walls during expansion, per cent, 4.1.

Adiabatic exponent for expansion without heat loss, 1.216.

Work done per cycle, ft-lb. per std. cu. in., 21.9.

Indicated mean effective pressure—$21.9 \cdot 12 \cdot \frac{4.57}{6.40}$ lb. per sq. in., 188.

In this computation the work done is 21.9 ft-lb. per std. cu. in. as found by taking the difference in the work done during the expansion and compression strokes by a polytropic compression and expansion. Multiplying by the fraction 4.57/6.40 converts the units into foot-pounds per cubic inch of cylinder volume, while the factor 12 reduces the units to in-lb. per cu. in. = lb. per sq. in.

Since the brake mean effective pressure was 164 lb. per sq. in., the mechanical efficiency was 87 per cent.

Air-Injection-Diesel Card

Fig. 6 shows the diagram of a slow-speed air-injection type of Diesel engine. The suction temperature for this card was 660 deg. fahr. absolute and the residual-gas temperature 1500 deg. fahr. absolute. In calculating the suction temperature, naturally no allowance was made for evaporation of the fuel. The temperature rise due to the exchange of heat between the cylinder walls and intake valve and the incoming fresh charge was assumed to be 100 deg. fahr. since the engine was running relatively cool.

Since nearly 10 per cent of additional air was injected with the fuel, the volume increase was taken to be 15 per cent for this diagram. The combustion is seen to have continued over most of the expansion stroke, whereas fuel injection occurred during the period of relatively rapid combustion. Lacking definite information as to the time variation of the rate of flow of the compressed air into the cylinder during the injection period, it has been assumed that the value of *a*, which is determined by the combined injection and combustion, is proportional to the increase in volume shown on the indicator card. The upper isothermal accordingly is a 45-deg. line for only a small portion of the stroke, and for the remainder of the stroke has a varying slope slightly less than 45 deg.

The point of maximum temperature found by drawing a 45-deg. line tangent to the expansion line is the point *b*. However, since the combustion was not complete in the point *b* and the factor *a* is therefore not a constant but is decreasing in value, the isothermal axis actually has a slope slightly less than 45 deg. at that point.

By drawing the true maximum-temperature isothermal parallel to the isothermal axis, the maximum-temperature point was found to be the point *e* instead of the point *b*. The two points, however, are quite close together so that the error caused by using the 45-deg. line for the determination is small. Both points are virtually at the same temperature. The maximum temperature of the cycle as measured at each point was 3050 deg. fahr. absolute.

The heat input to the charge, neglecting losses, was found by taking the difference in the internal energies at the points *a* and *c* and adding the work done by the constant-pressure expansion from *a* to *c*. The difference in the internal energies is 18.5 ft-lb. per std. cu. in. while the work done by a constant-pressure expansion from *a* to *c* is 6.4 ft-lb. per std. cu. in. Thus the heat input to the charge was 24.9 ft-lb. per std. cu. in.

The temperature of the combustion gases at the end of the

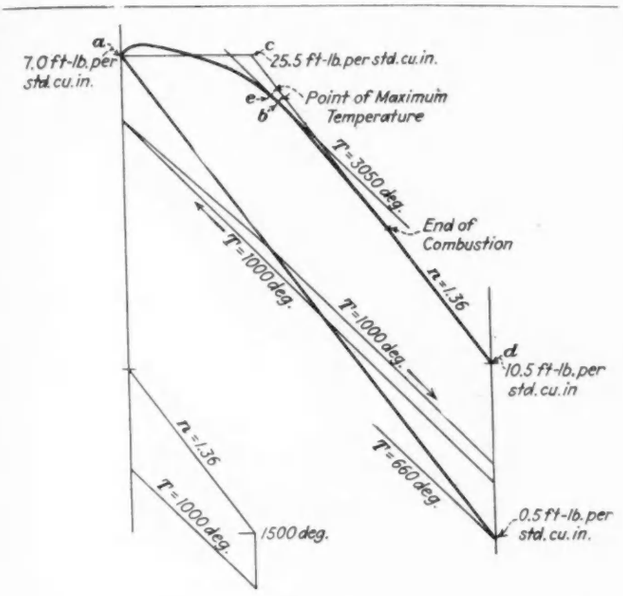


Fig. 6—Diagram of a Slow-Speed Air-Injection Type of Diesel Engine

expansion stroke was found to be 2050 deg. and the heat carried off 10 ft-lb. per std. cu. in.

The work done in going from *a* to *c* as shown above was 6.4 ft-lb. per std. cu. in., while that done from *c* to *d* was 12.9 ft-lb. per std. cu. in. Thus the total work done during the expansion stroke was 19.3 ft-lb. per std. cu. in. Since the work done during compression was 7.1 ft-lb. per std. cu. in., the net work done during the cycle was 12.2 ft-lb. per std. cu. in. or 49 per cent of the heat input to the charge. Since 40 per cent of the heat input went to the exhaust gases, 11 per cent or 2.7 ft-lb. per std. cu. in. was lost to the cylinder walls during the expansion stroke. The indicated mean effective pressure was found to be:

$$12.2 \cdot 12 \cdot \frac{9.53}{13.6} = 103 \text{ lb. per sq. in.}$$

Here the work done is 12.2 ft-lb. per std. cu. in. and 13.6 is the cylinder volume in terms of the compression ratio, while 9.53 is the volume of the cylinder charge at standard temperature and pressure.

With a mechanical efficiency of 85 per cent, the brake mean effective pressure would be 87 lb. per sq. in.

Summary

A simple method of measuring cylinder temperatures in the logarithmic diagram has been described. It has been shown further that the residual-gas temperature and the temperatures during the exhaust stroke can also be measured readily. Curves are given whereby the internal energy of the charge can be determined, once its temperature is known. The curves also make it possible to correct the temperatures measured in the logarithmic diagram for dissociation.

Several indicator diagrams have been analyzed in order to show what can be learned from the logarithmic diagram and how this method of analysis can be applied to various types of indicator cards. It is possible to determine the heat input to the charge, neglecting heat losses to the cylinder walls during combustion and the losses due to the unburned fuel. The indicated power-output and the indicated mean effective pressure can be determined readily from the logarithmic diagram. The heat in the exhaust gases at the end of the expansion stroke can also be determined easily.

The heat loss to the cylinder walls during the expansion stroke was also found. This loss, being approximately only one-quarter of the total heat loss to the cylinder walls, indicates that a large proportion of the total loss must be absorbed by the cylinder walls and exhaust valve during the exhaust stroke.

The adiabatic exponent for the expansion was approximately 0.04 smaller than the actual exponent for the two cases in which it was determined. The effect of the change in specific heat with change in temperature on the adiabatic exponent is shown by the values of the adiabatic exponent 1.300 and 1.216 which were obtained in two of the diagrams under very different temperature conditions.

It was shown also that with no heat loss during the expansion stroke the gain in power-output of the engine is only about 2 per cent, while at the same time the heat contained in the exhaust gases increased around 7 per cent.

Discussion

Logarithmic Diagram Answers Many Practical Questions

—Dr. H. C. Dickinson
National Bureau of Standards

REFERRING to Mr. Gregory's paper discussing the uses of the logarithmic diagram, I have long been surprised and puzzled by the fact that this extremely powerful tool has been so neglected. Its possibilities in the solution of practical problems are only suggested by the interesting examples which Mr. Gregory cites.

There may be two reasons for the long neglect of this tool. The physical significance of a straight-line plot on logarithmic paper is very difficult for most of us to grasp. I confess my own inability to picture clearly what it means in mechanical terms. However, it is not over-difficult to learn its meaning and the possibilities of its use in much the same way that one uses a slide rule or a log table without keeping in mind any of the steps whereby the tool has been developed.

To use a simpler illustration, one uses a lathe or a milling machine without picturing the operation of the gearing which makes it work the way it does. One may wish to have, for his own satisfaction, a clear picture of the mathematical processes whereby the log table or the slide rule have been calculated, or a picture of what is going on in the lathe apron or the transmission gear of a motor car, but in none of these cases is such knowledge necessary to the use of the tool.

Perhaps a more important reason for the neglect of the logarithmic diagram is that in most cases it does not give accurate figures. In fact, it must be used with discretion to get even useful results. However, when so used, it does give results amply accurate to answer many practical questions which can be answered only with great difficulty, if at all, by any other method. In fact, in many cases, the methods of

tedious calculation otherwise which would be required are not any more accurate, often less so. They all involve about the same assumptions and approximations.

I believe there has been a strong tendency among engineers, as well as scientists, to neglect or reject, for lack of accuracy, tools like this which give useful practical results. We are often too lazy to calculate what their accuracy really is. I should like to emphasize again the practical usefulness of the tool which Mr. Gregory has tried to sell you. It will add a lot to our practical knowledge of what is going on in engine cylinders if its use becomes common practice.

Method Seemingly Applicable to Wide Range of Card Types

—Eugène Fezandié
Stevens Institute of Technology

WHILE the use of the logarithmic diagram as applied to the indicator card is not new, Mr. Gregory has made a very valuable contribution in his analysis of events in the cycle. The method is simple and direct. The probable accuracy of results appears to be well within the limits of usefulness. As far as I know, his method employing the use of isothermals for obtaining maximum temperature has not previously appeared.

I believe that his use of Ricardo's energy-temperature diagrams should permit fairly accurate investigation of indicator cards. Apparently, the method is applicable to a rather wide range of card types.

Two Points Which Introduce Errors

—L. C. Lichty
Yale University

MR. GREGORY'S paper presents a method for analyzing indicator cards which, in principle, is excellent but which, in application, is in considerable error. There are two points upon which the analysis depends which introduce the errors in question; namely, (*a*) the determination of temperature on the expansion curve from the indicator card, and (*b*) the extrapolation of the expansion curve and the use of temperatures and energies at the extrapolated points.

The determination of temperatures on the expansion curve of the indicator card involves the use of change of mols during the combustion process which has been handled in a good practical manner by having a separate 1000 deg. fahr. absolute line for expansion temperatures located a distance above the 1000-deg. line for compression temperatures. While dissociation would tend to raise this expansion axis, the error is negligible (about 0.8 per cent) if a mean value for the mols of products is used for drawing the base line. However, writing the equation for the products and for the mixture, on a mol basis,

$$P_P V_P = M_P R T_P$$

and

$$P_m V_m = M_m R T_m$$

and then correcting on the indicator diagram for the difference in mols of the products and mixture, it can be seen that at a given volume

$$\frac{P_P}{P_m} = \frac{T_P}{T_m}$$

Thus the pressures are a direct measure of the temperatures. In the case of the supercharged engine the maximum temperature as measured from the diagram is 6200 deg. fahr. absolute. This is the mean temperature of the gases required to produce the pressure at that point. The author is in error in correcting this value to 5400 deg. fahr. absolute due to dissociation, since at that temperature the pressure would be considerably less than the indicator card showed. The only correction that need be applied is that due to the difference between the mols of products for complete combustion and the mols of products for the dissociated condition existing at 6200 deg. fahr. absolute. This would not be more than 1 per cent correction and would reduce the temperature to about 6150 deg. fahr. absolute instead of 5400 deg. fahr. absolute. The principle involved is that the sensible energy fixes the temperature which, in turn, fixes the pressure in this case. Thus at 6150 deg. fahr. absolute (Fig. 3, author's paper) the sensible energy is 52.5 ft-lb. per std. cu. in. and the chemical energy in the dissociated products is about 18.5, making a total of 71 ft-lb. per std. cu. in.

Extrapolating the expansion curve toward higher pressures, particularly, is a dangerous procedure. This is due to the effect of temperature on the specific heats which determine the adiabatic exponent, and cause it to increase with a drop in temperature; also, the burning of the dissociated products which liberates chemical energy tends to reduce the exponent of the curve of expansion, while heat loss to the cylinder tends to increase the exponent. Thus there are three factors which make the expansion process a curved line on logarithmic paper, which makes extrapolation at the higher end of the curve a very inaccurate procedure.

A further error in extrapolating the expansion curve is shown in Fig. *A*. Starting at *B*, the total energy of the mixture is the internal energy *E* and chemical energy *C*. Fol-

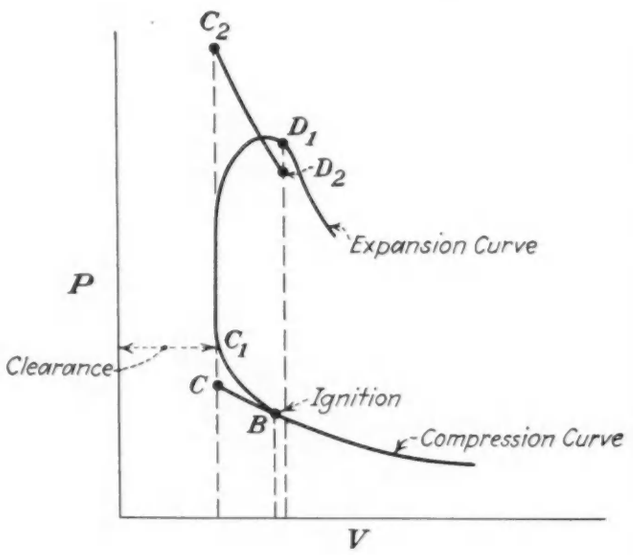


Fig. *A*—Illustrating a Further Error in Extrapolating the Expansion Curve

lowing the path BC_1D_1 and then BCC_2D_2, the energy at $D_1 = E_B + C + W_BC_1 - W_{c_1}D_1$; while at D_2 the energy is equal to $E_B + C + W_BC - W_{c_2}D_2$, where W is the work between the points in question and is the area under the curve connecting the points.

Since

$$(W_{c_2}D_2 - W_BC) > (W_{c_1}D_1 - W_BC)$$

it is obvious that the energy at D_2 is less than that at D_1. Therefore, D_2 is below D_1, as shown, and the expansion curve extrapolated will cross the clearance volume line above C_2 which is already the highest attainable value, since no work is done by the gases during the imaginary combustion process to C_2.

The use of the incorrect temperatures and also of extrapolated values makes the heat loss determinations very inconsistent. Referring to the supercharged-engine card, the heat loss during expansion is given as 4.1 per cent or 0.041 x 85.7 = 3.5 ft-lb. This appears much too low for the temperatures along the expansion curve, since the Hispano-Suiza example shows 7.9 per cent, and the air-injection Diesel shows 11 per cent.

Examination of the assumed constant-volume combustion-process of the supercharged-engine card shows an increase in total energy of 8.1 to 62.6 ft-lb., or 54.5 ft-lb. Since no work is done in this process the increase in total energy plus the heat loss must equal the energy supplied. Thus 54.5 + heat loss = 85.7 ft-lb. and the heat loss = 31.2 ft-lb. This is 36.4 per cent loss and is entirely too high for the process. Thus the method used reduced the imaginary temperature at clearance volume to such a point that the eneregy values (such as 62.6) are so low that the heat loss determinations for both combustion and expansion are very much in error.

A more accurate analysis of the supercharged-engine card for the combustion and expansion part of the card follows:

		Ft-Lb.
Temperature at ignition point, 1680 deg. fahr. absolute	E_1	= 7.5
Maximum temperature, 6150 deg. fahr. absolute	E_2	= 71.0
Work of compression from ignition to top dead-center	W_{in}	= 0.4
Work of expansion from top dead-center to maximum temperature	W_{out}	= 5.7
Heating value of the charge	H_V	= 85.7

Then applying the energy equation[1]:

$$E_1 + H_V + W_{in} = E_2 + W_{out} + Q_{loss} \text{ or}$$
$$7.5 + 85.7 + 0.4 = 71 + 5.7 + Q_{loss} \text{ or}$$
$$Q_{loss} = 16.9 \text{ ft-lb. or}$$

19.7 per cent loss of energy to the cylinder walls during the combustion process.

		Ft-Lb.
At a maximum temperature of 6150 deg. fahr. absolute	E_2	= 71.0
At the end of expansion, T = 4300 deg. fahr. absolute and	E_3	= 34.5
Work out during expansion from (2) to (3)	W_{out}	= 20.1

Applying the energy equation

$$E_2 = E_3 + W_{out} + Q_{loss} \text{ or}$$
$$71.0 = 34.5 + 20.1 + Q_{loss} \text{ or}$$
$$Q_{loss} = 16.4 \text{ ft-lb. or}$$

19.1 per cent energy loss to the cylinder walls during expansion.

These values for heat loss, 19.7 per cent during combustion and 19.1 per cent during expansion, certainly represent more nearly the actual distribution of heat loss than do the values 36.4 per cent and 4.1 per cent respectively. The total heat loss from the ignition point to the end of expansion, 38.8 per cent as corrected against 40.5 per cent, should check if the temperature at the end of expansion had been correctly determined and if the author's analysis had been confined to the card instead of extrapolating.

A more detailed analysis[2] of an indicator card in which the various curves have been examined in many more sections resulted in a heat loss, during the period from ignition to a point on the expansion curve having the same volume, of 12.5 per cent. The heat loss on the expansion curve from the foregoing point was found to be 13.2 per cent, making a total heat loss of 25.7 per cent from ignition to the end of expansion. This makes the total of 38.8 per cent for the supercharged engine to appear high. However, the mean temperature of the gases during expansion was about 5200 deg. fahr. absolute for the supercharged engine compared to 3600 deg. fahr. absolute for the example cited. This should increase the heat loss about 60 per cent, considering the effect of different cylinder wall temperatures. Thus the 38.8 per cent heat loss does not appear out of line, although leakage losses may have had some influence in increasing the apparent heat loss.

[1] Assuming that the chemical energy H_v is equal to the heating value.
[2] See Internal-Combustion Engines (4th edition), by Streeter and Lichty, pp. 427 to 432.

Air Transport Needs of the Private Owner

(Excerpts from paper entitled "Air Transportation Equipment for the Private Owner" presented at the Annual Meeting, Detroit, Jan. 16, 1935, by John H. Geisse, chief, Aeronautics Development Section, Bureau of Air Commerce, Department of Commerce.)

IT IS quite unfortunate that there seems to be a tendency on the part of many in the industry to believe that purchasers buy airplanes only to learn how to fly present types of equipment and that the small airplane should first of all be suitable as a trainer. Automobiles are not purchased for the purpose of learning how to drive them, radios are not purchased to learn how to operate them, and not until we build and sell airplanes for a purpose other than that of teaching their owners to fly will we enjoy the volume of business to which the aviation industry is presently entitled.

True it is that material reductions in costs of airplanes would also tremendously increase their private use. However, the Bureau of Air Commerce from a consideration of accident records has seen fit to require 50 hr. solo time before a pilot may take up his friends. At present rates the accumulation of this time entails an outlay of about $500, and savings in this item are just as effective in reducing cost of ownership as equivalent reductions in the cost of the plane. When we talk of bringing cost levels down comparable to automobiles, it is foolish to start out with a training charge which is in itself equal to the cost of an automobile. Furthermore, material reductions in costs will require quantity production, and, unless either private capital or the Government is willing to take the risk of financing production in advance of

sales, then sales must lead production and cost reductions will have to wait on sales increases.

The airplane suitable for private flying must be as simple to fly and as safe as present knowledge will permit us to produce. It is unnecessary and, considering the characteristics of the conventional training plane, undesirable that this plane have controls and flying characteristics similar to those of present types. The need for flight instruction—that is, the instruction required to permit the owner to fly locally with safety—must be reduced to the point where it is a minor item for which there is no extra charge. Men, not supermen, constitute the market.

Let us consider some of the peculiarities of present aircraft which can hardly be said to enhance their value as a means of air transportation for the private owner.

First let me mention the powerplant, since I have referred to its deficiencies on several previous occasions. On the extremely flimsy and unacceptable excuse that the propeller makes most of the noise anyway, no effort has been made whatever to quiet the aviation engine. If the engine in any prospective purchaser's automobile made one-half the racket that he hears from the aviation engine, he would immediately cut the switch and have the car towed to a garage for fear that continued running would wreck it beyond repair. I cannot help but feel that the average layman's desire to ride in an airplane is cut in half as soon as he sees and hears the engine being started and warmed up, even before the propeller noise has become pronounced. There is no excuse for this condition. The aviation engine can be, should be, and will be developed to be not appreciably rougher or noisier than the automobile engine.

Now let us turn to consideration of the flying characteristics of the average airplane at present offered for private air transportation. I would like to ask you first just what you would think of an automobile whose brakes were not effective between its top speed and say 45 m.p.h. You must admit that this would be an absurdity, but it is exactly what we attempt to sell in an airplane. This is not a far fetched analogy.

The advantages of a type of landing chassis which permits landing at any speed with immediate and full application of the brakes have been demonstrated with the Stout Skycar and more recently with the Weick W-1 plane. In a series of trials with the latter at Langley Field, novice pilots with less than 15 hr. flying time could land repeatedly in a much smaller space than was required by expert pilots with a plane having a conventional landing gear. The reason should be manifest. In the conventional airplane the pilot has not only the position of the airplane to consider but also its speed. He must have excellent judgment to get the plane to the right position at the right speed. With the so-called three-wheel landing gear, the position of the plane is about all that needs consideration.

A breakdown of the 102 fatal accidents in non-scheduled flying for the last half of last year shows that for all pilots—which includes transport pilots not engaged in scheduled air line operation—46 per cent of the fatal accidents are due to stalling or spinning and 55.7 per cent of the serious accidents are also due to this cause. Again it is interesting to note that, as the level of experience of the pilot is reduced, the percentage of accidents due to spinning or stalling increases appreciably—58.8 per cent for fatal accidents and 67.6 per cent for serious accidents. Certainly the records seem to bear out the statement credited to Mr. Ford that present flying is 90 per cent pilot and 10 per cent airplane.

Faced with such facts, the officials of the Bureau of Air Commerce would be derelict to their duty and would be neglecting their greatest opportunity to further the private use of aircraft if they were to take no corrective measures. The choice of steps rested between the issuance of regulations which would compel all manufacturers to discontinue their present types and develop new models having the safety features which can now be incorporated in all aircraft, and sponsoring the development of such an airplane to demonstrate its possibilities and lead the industry to make the necessary changes of its own accord. Strong representations for the former course were presented to the Bureau, and it is quite likely that such regulations will have to be made eventually. The alternate course, certainly much more favorable to the present manufacturers, was chosen and every effort will be made to follow it to a successful conclusion.

Letter Comments on Recent Flame Temperature Paper

Editor, S.A.E. JOURNAL:

In a current paper[1] Rassweiler and Withrow refer to an earlier paper of mine[2], and quote observations plotted in Fig. 9 of this paper. Maximum radiation intensity recorded from the knocking zone was markedly less than from a zone close to the sparkplug, but I said at that time ". . . it is difficult to explain why the maxima of curves *B* and *D* should differ so greatly; until some calibration test can be devised which will take account of both thermocouple sensitivity and accuracy of focusing the question will have to remain in abeyance." A calibration test was devised later, and although *there still remains some doubt about the absolute scale of ordinates* for radiation intensity from different zones in the engine cylinder, a plot of the latest results shows radiation from the knocking zone as slightly greater than that from the zone near the sparkplug[3].

Thus, the observation for which Rassweiler and Withrow offer an explanation in terms of temperature gradient was originally presented with a strict reservation intended to preclude direct quotation, and was subsequently shown to be profoundly influenced by the factors mentioned in the reservation.

Furthermore, if radiation intensity is (as I believe) initially due, in some measure, to chemiluminescence, energy considerations lead to the conclusion that maximum radiation intensity from a zone where temperature is lower should be greater than from a zone where it is higher.

Sydney Steele

Harvard University,
Cambridge, Mass.

[1] See S.A.E. JOURNAL, April, 1935, pp. 125-133.
[2] See *Industrial and Engineering Chemistry*, 1933, vol. 25, pp. 388-393.
[3] See N.A.C.A. 1934 Report No. 486.

Dr. R. E. Wilson says:

● "Up-to-date technical knowledge, enthusiasm for one's profession, and acquaintance with one's fellows, are the foundation stones of success in any profession.

"For automotive engineers, the S.A.E. is an indispensable source of all three."

THE recent election of Dr. Wilson as vice-chairman of the board of directors of the Pan-American Petroleum & Transport Co., serves to bring to the forefront the fact that many automotive engineers are also automotive executives—and the Society of Automotive Engineers is for both.

Since joining the S.A.E. in 1921, Dr. Wilson has contributed his time and ability to many of the Society's undertakings. From his statement at the left of this page, we believe he has felt his S.A.E. association to be worthwhile.

THIS PAGE IS SPONSORED FOR THE INSPIRATION OF OUR PRESENT MEMBERS—FOR PRESENTATION TO PROSPECTIVE MEMBERS—BY

THE SOCIETY OF AUTOMOTIVE ENGINEERS, INC.

Twenty-nine West Thirty-ninth Street, New York

New Members Qualified

These applicants who have qualified for admission to the Society have been welcomed into membership between March 10, 1935, and April 10, 1935.

The various grades of membership are indicated by: (M) Member; (A) Associate Member; (J) Junior; (Aff.) Affiliate Member; (SM) Service Member; (FM) Foreign Member.

ANDERSEN, LLOYD C. (A) 905 East 34th Street, Vancouver, Wash.

AUL, RUSSELL W. (A) superintendent of transportation, Jersey Central Power & Light Co., Asbury Park, N. J.; (mail) 501 Grand Avenue.

BARLOW, THOMAS MORGAN, Major (FM) director, chief engineer, Fairey Aviation Co., Ltd., Hayes, Middlesex, England.

BITTNER, RAYMOND (J) engineer, Smith Aircraft, 1338 South Michigan Avenue, Chicago; (mail) 2247 South Irving Avenue.

BROWER, GILBERT K. (M) chief chemist, American Airlines, Inc., Robertson, Mo.

BROWNSON, HAROLD N. (J) experimental department, Olds Motor Works, Lansing, Mich.; (mail) 327 West Lenawee Street.

CLOHISY, WARREN A. (A) president, W. A. Clohisy, Inc., 650 North Western Avenue, Chicago.

DEACON, BRUCE WELLINGTON (A) sales engineer, D. A. Stuart Co., 2727 South Troy Street, Chicago; (mail) 154 Pilgrim Avenue, Highland Park, Mich.

DONNELLY, JOSEPH A. (A) district manager, Autocar Co., Ardmore, Pa.; (mail) 1716 West Pershing Road, Chicago.

FAULKNER, GEORGE (A) president, George Faulkner Co., 1226 South West Stark Street, Portland, Ore.

FLEMING, HARVEY CARRUTHERS (A) manager, coach division, White Motor Co., 2401 Archer Avenue, Chicago.

GREGORY, ALFRED THORNE (M) test engineer, Wright Aeronautical Corp., Paterson, N. J.; (mail) Lock Box 15, Butler, N. J.

HARRISON, JOHN, JR. (A) president, Charles F. Kellom & Co., Inc., Holmesburg Station, Philadelphia.

HAWLEY, SPENCER H. (A) superintendent of maintenance, Auto Interurban Co., Spokane, Wash.

HENDERSON, CLAUDE LYLE (F M) mechanical engineer, Public Works Dept., Perth, Western Australia.

HOLBROOK, DARWIN L. (A) sales engineer, Fafnir Bearing Co., Booth Street, New Britain, Conn.

KERR, JAMES (A) service engineer, Associated Equipment Co. of Canada, Ltd., Room 908, Keefer Building, Montreal, Quebec, Canada.

KNOWLES, H. R. (A) general superintendent, service station, Imperial Oil, Ltd., 56 Church Street, Toronto, Ontario, Canada.

LEONARD, ALFRED S. (A) service manager, Sterling Motors Corp., Los Angeles; (mail) 2315 East Ninth Street.

MARTIN, CHARLES JAMES (M) chief engineer, F. Coleman & Sons, Detroit; (mail) 7725 Middlepointe Avenue, Dearborn, Mich.

MATTHEWS, THOMAS JOHN (M) engineer, Atlas Supply Co., 744 Broad Street, Newark, N. J.; (mail) 55 Hanson Place, Brooklyn, N. Y.

MCCLUER, WILBERT B. (M) chemical engineer, Kendall Refining Co., Bradford, Pa.

MUNSON, AMOS KELLER (M) engineer of construction, United Traction Co., 598 Broadway, Albany, N. Y.

NORDLINGER, S. G., 1st Lieut. (J) U. S. Army, Engineer Research, 353rd Co. CCC, Camp S-53, Clear Creek, Sigel, Pa.

OBERREUTTER, PAUL H. (M) president, dynamometer engineer, Mid-West Dynamometer and Engrg. Co., 5948-50 South Western Avenue, Chicago.

ORMISTON, GERALD (F M) controller of factories, Dunlop Perdriau Rubber Co., Ltd., Flinders Street, Melbourne, Australia.

OVENS, WILLIAMS GEORGE (J) test engineer, Wright Aeronautical Corp., Paterson, N. J.; (mail) 1149 First Avenue, Hawthorne, N. J.

PHILLIPS, C. S. (M) automotive engineer, John Bean Mfg. Co., Lansing, Mich.

PROCELLER, WM. A. (A) solvent salesman, Socony Vacuum Oil Co., Inc., 5502 Avenue U, Brooklyn, N. Y.; (mail) 159 Logan Street.

PROSSEN, LOUIS F. (J) timekeeper, Archer Daniel Medland Co., Edgewater, N. J.; (mail) 30 Cortland Place, Cliffside, N. J.

REED, HERBERT B. (J) assistant manager, National Reemployment Service, Conway, N. H.; (mail) Collins Block, Main Street.

REICHARDT, OTTO A. (J) foreman, Public Service Coordinated Transport, 80 Park Place, Newark, N. J.; (mail) 914 South Grove Street, Irvington, N. J.

ROACH, E. D. (A) sales manager, equipment division, central division, Edison-Splitdorf Corp., 122 South Michigan Avenue, Chicago.

ROSE, ROWLAND S. (J) assistant design engineer, Wentworth & Irwin, 123 North East Oregon Street, Portland, Ore.; (mail) 2947 North East 10th Avenue.

ST. JOHN, R. C. (J) draftsman, N.R.W.R. Office, State Highway Department, Bismarck, N. D.; (mail) Post Office Box 271.

SPATTA, GEORGE (M) chief engineer, Clark Equipment Co., Buchanan, Mich.

STAPLETON, H. N. (J) instructor, Pennsylvania State College, Department of Agricultural Engineering, State College, Pa.

STITZ, ERVIN O. (J) draftsman, Ross Gear & Tool Co., Lafayette, Ind.; (mail) 411 Lingle Avenue.

THOMAS, ALDEN PEACH (J) Diesel engineer, Timken Roller Bearing Co., Canton, Ohio; (mail) 123-32nd Street, North West, RFD 2.

VAN SINDEN, CARL H. (A) commercial sales manager, General Tire & Rubber Co., Akron, Ohio.

VESPER, HOWARD G. (M) assistant to eastern manager, Standard Oil Co. of California, 30 Rockefeller Plaza, Room 4225, New York City.

WECKER, WILLIAM A. (M) president, general manager, Hayes Wheels & Forgings, Ltd., Merritton, Ontario, Canada.

WENTZ, CHESTER L. (M) lubrication sales engineer, Penola, Inc., 34th & Smallman Streets, Pittsburgh, Pa.; (mail) 16540 Birwood Avenue, Detroit.

WIMAN, CHARLES DEERE (A) president, Deere & Co., 1325 Third Avenue, Moline, Ill.

Applications Received

The applications for membership received between March 15, 1935, and April 15, 1935, are listed herewith. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ALDINGER, FRED, assistant chief engineer, export department, The Texas Co., New York City.

BOARDMAN, CARLTON E., service manager, McAthey & Sons, Viking, Alberta, Canada.

BODEN, HAROLD, partner, Boden & Bassingthwaite, Toronto, Ont., Canada.

BORGQUIST, JOHN W., gear matcher, Buick Motor Co., Flint, Mich.

BRAY, WILSON C., manager truck and bus tire department, B. F. Goodrich Co., Akron, Ohio.

BRUENING, J. M., president, The Ohio Ball Bearing Co., Cleveland, Ohio.

BUEMI, ANTHONY CHARLES, machinist, Harris-Calorific Co., Cleveland, Ohio.

COSGRAVE, EARL JOHN, representative, Fox Co., Cincinnati, Ohio.

COY, FRANK, superintendent, McQuay Norris Mfg. Co. Ltd., Mount Dennis, Ont., Canada.

DOUGLASS, EDGAR J., 6430 Apple St., Pittsburgh, Pa.

DOWLING, CHESTER E., service superintendent, George P. Peterson, Oakland, Cal.

ECHLIN, J. E., president, Echlin & Echlin Inc., San Francisco, Cal.

EDGE, STANLEY HOWARD, designer, The Clayton-Dewandre Co. Ltd., Lincoln, England.

EDWORTHY, THOMAS P., manager, Prairie Cities Oil Co., Ltd., Winnipeg, Canada.

ELDRIDGE, MAURICE J., brake mechanic, Goodrich Silvertown Stores, Cedar Rapids, Iowa.

FELT, ARTHUR E., foreman, Henderson Produce Co., Laclede, Mo.

FLANNIGAN, ARTHUR WILLIAM, superintendent of service, Day-Majer Co., Spokane, Wash.

GOBETTI, JOHN P., 19 Christopher St., New York City.

GOULD, JACK, assistant maintenance engineer, Saskatchewan Power Commission, Regina, Sask., Canada.

HATCH, JAMES R., research technician and code adviser, Labor Advisory Board, Washington, D. C.

HAWXWELL, FREDERICK WILLIAM, director, Hawxwell & Jones Ltd., Sydney, N.S.W., Australia.

HERSCHEL, CARL, draftsman, U. S. Rubber Products Inc., Indianapolis, Ind.

HODGSON, ALFRED, service manager, Trinidad Agencies Ltd., Trinidad, British West Indies.

HOLLAND, L. D., western sales manager, E. F. Houghton & Co., San Francisco, Cal.

HOOVER, RAY B., secretary-treasurer, Shafer Bearing Corp., Chicago, Ill.

JOYCE, REGINALD, engineer, Consumers' Research Inc., Washington, N. J.

KAUFFMAN, FRANK EDGAR, engineer, American Hammered Piston Ring Co., Baltimore, Md.

KELLER, WALT, district manager, Aetna Ball Bearing Manufacturing Co., Detroit, Mich.

KUEHN, ERNEST, production manager, Electro-Motive Corp., Cleveland, Ohio.

LAURIE, GAVIN W., manager, automotive transportation, The Atlantic Refining Co., Philadelphia, Pa.

LEVENSTEIN, SHERMAN T., research metallurgist, Federated Metals Corp., Detroit, Mich.

LINDBLOOM, ALBERT C., president, Lindbloom Auto Parts Co., Chicago, Ill.

LINTHICUM, CHARLES M., agent, Gulf Refining Co., Baltimore, Md.

MANSON, ARTHUR, owner, Garden City Sales and Service Co., San Jose, Cal.

MARTIN, ERLE, assistant chief engineer, Hamilton Standard Propeller Co., Hartford, Conn.

MATHER, THAMBIAH, chief engineer, The Jeffna Imperial Motor Works Ltd., Manipey, Ceylon.

MURRAY, HARRY E., machinery salesman, Grace Brothers, Ltd., Honolulu, T. H.

NIXON, THOMAS HAY, Capt. U. S. Army, Washington, D. C.

PAULSON, ROY A., service engineer, United Motors Service, Detroit, Mich.

PELKE, ARTHUR A., service instructor, Chevrolet Motor Co., New York City.

PIERCE, EROLD FRANCIS, test engineer, Wright Aeronautical Corp., Paterson, N. J.

PRESS, JACOB HENRY, JR., motor truck bodies, Jacob Press' Sons, Chicago, Ill.

RANGE, HOWARD JOSEPH, sales manager, Cochran & Celli, Oakland, Cal.

REYNOLDS, BENJAMIN S., vice-president, Burgess Battery Co., Madison, Wis.

RHODES, WILLIAM V., petroleum products, Shell Petroleum Corp., Detroit, Mich.

RICE, HAROLD G., manager, Pioneer Motor Bearing Co., San Francisco, Cal.

ROBINSON, JOHN A., district manager of sales, Timken Roller Bearing Co., Canton, Ohio.

RODGERS, ROY D., mechanic, Canada Motor Sales, Ottawa, Ont., Canada.

RUEGG, MAX, designer, Cadillac Motor Car Co., Detroit, Mich.

SEESE, MELVIN EDWARD, tool grinder, Studebaker Corp., South Bend, Ind.

SELLEY, CHARLES HENRY, deputy manager, motor department, Shell-Mex and B. P. Ltd., London, England.

SMITH, H. PERRY, vice-president and secretary, W. G. B. Oil Clarifier Inc., Kingston, N. Y.

SMITH, HOWARD M., bus foreman, South Pennsylvania Bus Co., Chester, Pa.

SOCIETE FRANCAISE HISPANO SUIZA, Bois-Colombes (Seine), France.

STERN, DR. RICHARD, manager of lubricating division, Shell Petroleum Corp., St. Louis, Mo.

STREBE, M. F., engineer, Ross Gear & Tool Co., Lafayette, Ind.

SULZMAN, EDMUND CHESTER, layout draftsman, Wright Aeronautical Corp., Paterson, N. J.

SUTTLES, LIEUT. ERNEST A., transportation, U. S. Army, Fort Williams, Maine.

THOMSEN, NEIL C., foreman, Wright Aeronautical Corp., Paterson, N. J.

TOMPSETT, ELLIOT W., Sinclairville, N. Y.

TWEEDALE, ARTHUR, principal, A. Tweedale, Blackpool, Lancashire, England.

UNTERMYER, SAMUEL, 2nd, Sinclair Refining Co., East Chicago, Ind.

UTAS, AUGUSTUS, service manager, Universal Service, Vegreville, Alta., Canada.

WALLACE, ROBERT C., assistant chief engineer, Marmon-Herrington Co., Inc., Indianapolis, Ind.

WEHMEYER, ARTHUR H., assistant chief engineer, Wisconsin Motor Corp., Milwaukee, Wis.

WHIPPLE, LEON VINCENT, tool designer, Trico Products Corp., Buffalo, N. Y.

WILSON, W. E., Bower Roller Bearing Co., Detroit, Mich.

YANCEY, LEWIS A., aviator, Champion Spark Plug Co., Toledo, Ohio.

Meetings Calendar

S.A.E. 30th Anniversary Summer Meeting

The Greenbrier, White Sulphur Springs, W. Va., June 16-21, inclusive.

Baltimore—May 2

Holabird Quartermaster Depot, Camp Holabird, Md. Motor Truck Transportation Show 2:00 P. M. to 7:00 P. M.; dinner at the Army Field Kitchen.

Buffalo—May 14

Statler Hotel; dinner 6:30 P. M. Modern Airplane Transportation—speaker will be a representative from American Airways.

Canadian—May 15

Oshawa, Ont., at the plant of General Motors Products of Canada, Ltd.; trip through plant and golf in the afternoon. T. A. Boyd, Research Division, General Motors Corp., will be the speaker at the evening meeting.

Chicago—May 7

Hamilton Club (20 So. Dearborn St.); dinner 6:30 P. M. Bus Trends and Designs—F. R. Fageol, president, Twin Coach Co.

Dayton—May 9

The Dayton Engineers Club; dinner 6:30 P. M. Speaker—Arthur Nutt, vice-president in charge of engineering, Wright Aeronautical Corp.

Detroit—May 13

Book-Cadillac Hotel; dinner 6:30 P. M.

Metropolitan—May 13 and May 15

May 13—The Roger Smith; dinner 6:30 P. M. Discussion of 1935 Automobiles, with Harold F. Blanchard, editor of Motor Magazine, leading the discussion.

May 15—Demonstration and testing of 1935 automobiles, 10:00 A. M. to 5:00 P. M., at the Glenn Curtiss Airport, North Beach, Jackson Heights, N. Y.

Milwaukee—May 1

Trip through Belle City Malleable Iron Co. plant at Racine, Wis., 3:30 P. M.; dinner 6:30 P. M., Hotel Racine. Development of Electric Cast Iron—D. P. Spencer, metallurgist. Machineability, Engineering Properties and Application of Electric Furnace Cast Iron—R. J. Anderson, assistant superintendent, Belle City Malleable Iron Co.

New England—May 14

Northern California—May 14

Engineers Club, San Francisco; dinner 6:30 P. M. Question Meeting.

Northwest—May 10

New Washington Hotel, Seattle; dinner 6:30 P. M. Butane as Motor Fuel—G. L. Holzapfel, president, general manager, Holzapfel Instrument Co.

Philadelphia—May 8

Philadelphia Auto Trade Association; dinner 6:30 P. M. Piston Ring and Pistons—D. D. Robertson, chief engineer, Wilkening Manufacturing Co.

Pittsburgh—May 7

Pittsburgh Athletic Association; dinner 6:30 P. M.

Southern California—May 17

California Institute of Technology; dinner 7:00 P. M. High Altitude Flying—Doctor Rockefeller, California Institute of Technology.

Washington—May 6

University Club, Washington, D. C.; dinner 6:30 P. M. Chemical Warfare—Commander T. L. Schumacher (C.C.) U.S.N.

News of the Society

Papers by Gebhard & Ballard-Moore Create Lively Discussion at Detroit

● **Detroit**

THE relationship of piston rings to other engine parts; efficiencies of overdrive units and dual-ratio axles were topics which aroused valuable discussion at the March 18 meeting of the Detroit Section. Some 225 members and guests were present at the dinner meeting sponsored by the Passenger-Car Activity of the Section under Earl H. Smith, vice-chairman.

The first topic was introduced by J. H. Ballard and N. A. Moore, Sealed Power Corp. W. A. Gebhard, Case School of Applied Science, discussed overdrive and dual-ratio efficiencies.

Some of the points brought out by Mr. Moore were:

1. Piston design should facilitate quick flow of heat from the head into the skirt. Furthermore, top lands should be wide, not only to protect the ring from the heat of the head, but more important, to protect the ring from the hot gases of combustion. With a well designed piston head land clearance can be made quite small.

2. If pistons are not properly designed—if they distort and scuff—rings suffer badly from the carry-over of the metal. If the piston tends to "collapse" rings are tipped and their seal is broken, evidenced by riding of the ring lands on the cylinder wall.

3. Proper location of pin hole for piston balance is essential to prevent rocking or chattering, in which case rings cannot perform efficiently.

4. Distorted or snaky bores contribute materially to ring flutter. Ring design, involving narrower rings with higher unit pressures, etc., can only partially correct this condition.

5. Ring scuffing, a fairly recent phenomenon evidenced in the form of "washboarding" or knurling, is due to a local breakdown of the oil film, and is apparently caused by distortion at the top of the bore, surface conditions of the bore, and local hot spots. The first of these may be due in some cases to pulling down cylinder head bolts.

6. Pinning of the rings on the piston has been found an excellent means of locating the source of trouble and also of localizing the effect on the rings. Scuffing of rings is also found produced occasionally during the break-in period, substitution of a second or third set of rings not reproducing the phenomenon, and leads to the conclusion that reaction of surfaces to honing may be an important consideration.

7. In the manufacture of piston rings, control of raw materials is a difficult but important problem. Variations in iron produced have been traced, for instance, to variations in geological formation of the coal from which the coke used has been made. Atmospheric conditions during manufacture of pig iron may affect ring quality seriously.

In the discussion, in answer to questions by Chairman Earl Smith, Mr. Moore said that the importance of distortion of bores depends on extent of localization—that the latter produces scuffing of rings; no trouble has been experienced in recent years from snaky ring grooves.

In answer to Kingston Forbes, assistant chief-engineer, Buick Motor Car Co., Mr. Moore said that the phenomenon of ring flutter discussed comes in at definite engine speeds with a given engine and set of rings. He expressed belief that ring flutter starts at ring tips, the weakest part of the ring, and also that the phenomenon may be the result of operating at the natural period of vibration of the ring in the particular engine.

Ralph R. Teetor, chief engineer, Perfect Circle Co., pointed out that in modern engines rings would not follow cylinder walls at all if it were not for the combustion pressure back of the rings.

An interesting comment made by J. H. Ballard, chief engineer, Sealed Power Corp., was that engine friction does not necessarily increase with ring tension. In answer to a question on the effect of cylinder finish by C. W. Floss, consulting engineer, Detroit, Mr. Ballard said that smooth finishes were preferred in good bores, but that if bores were not perfectly straight, etc., rougher finishes were preferable.

Mr. Teetor also added some comments on ring flutter, stating that it was undetermined if the flutter condition were corrected by ring design, whether or not it might come in again at higher engine speeds, since this depended on many factors. The greatest amount of flutter, he said, was noticeable with light loads and high speeds.

Mr. Teetor said that, on the whole, it was easier to fit and design rings into a short-stroke engine, other conditions being equal. Both Mr. Teetor and Mr. Ballard agreed in answer to a question by P. J. Kent, chief electrical engineer, Chrysler Corp., that ring flutter was not caused by diaphragm action of the top of the piston.

Mr. Gebhard's paper, "A Study of the Efficiencies of Overdrive Units Used in Passenger Cars" was based on experimental investigation of the dual-ratio axle—as produced by the Columbia Axle Co., and the transmission type of overdrive unit as produced by the Warner Gear Co.

The investigations were confined to efficiency studies of the units themselves rather than to their operation in actual cars. From this standpoint Mr. Gebhard drew the conclusion that the axle method of overdriving is from 5 to 6 per cent more efficient than the transmission type method, his studies indicating that the efficiency comparison was more pronounced in the overdrive than in direct-drive positions.

This was attributable to the fact that "churning" losses increase in the overdrive position for the transmission type while they decrease in the axle type. For both units, however, efficiency increases at higher loads and speeds since churning and other losses are more than offset at higher speeds by the increased torque input and output.

Other specific findings mentioned in the paper, which was profusely illustrated by curves on lantern slides, included:

Axle Type

1. Lubricant content of the overdrive unit affected efficiency in inverse proportion. The unit should contain a minimum of lubricant consistent with operating safety.

2. With the dual-ratio axle tested the high ratio was found to be more efficient than the lower speed ratio above speeds equivalent to 50 m.p.h., indicating that around this speed a point is reached where the reduction in churning losses more than offsets the additional gear losses.

3. Roller bearings for the planetary assembly were found to increase the efficiency over the plain bushings. Needle bearings, on the other hand, showed about the same losses as with bronze bushings.

4. When operating with light spindle-oil to reduce churning losses at higher speeds, gear losses were shown to be greater at low speeds, and at low torques at high speeds this increase more than offsets decreased churning losses.

Transmission Type

5. No load losses are greater in overdrive than in direct, due partially to introduction of friction by the rollers in the over-running clutch. Churning losses also increase faster with engine r.p.m. in the overdrive position.

In the discussion of Mr. Gebhard's paper, H. T. Woolson, chief engineer, Chrysler Corp., pointed out that the difference in relative efficiencies of the two units tested were pretty small compared to the actual gains in economy made possible through the use of overdrives. Mr. Woolson stated that with the transmission type of overdrive as used on Chrysler Corp. cars gains of 15 to 20 per cent in gasoline economy with three times the normal oil mileage was experienced.

He added that the selection of the type of overdrive depended largely therefore on other factors, including the type of control. Mr. Woolson was of the opinion that a completely manual control for an overdrive unit was not desirable since it merely added complications in driving an automobile.

Pointing back to the experiences with four-speed transmissions, Mr. Woolson said that this had shown that people would not shift from one ratio to another to gain the possible advantages; that they would shift into the highest speed as soon as possible and stay there. He said that only part of this may have been due to the fact that third speed in those transmissions was not as quiet as it is possible to make the speeds of an overdrive mechanism.

Rosendahl Advocates Building More 'Ships

● **Metropolitan**

The construction of more large rigid airships for Naval scout and related service was strongly advocated by Lieut-Commander C. E. Rosendahl, U. S. Navy, in an address before the members and guests of the Metropolitan Section on April 8. He said in part that, despite the disasters which have overtaken all large American-built ships of this kind, the Commander indicated that we should profit by mistakes—which are inevitable in pioneering work—should be rectified by building more ships of this general type, because such craft are considered essential for Naval defense and there is no adequate substitute available or now in prospect. This, he said, is not a disparagement of long-range flying-boats, which may have important Naval applications but are not suited for the long-range scout-work with heavy loads which large rigid ships can perform. He cited the success of the Graf Zeppelin, with 68 Atlantic crossings and many other long flights to its credit, as an indication of what can be accomplished with ships of this character. He also pointed out that they cost only a fraction as much as large, fast, surface scout-cruisers and may prove even more effective because of greater speed and other advantages.

Prof. Alexander Klemin of New York University was the principal discusser and said that he agreed fully with Commander Rosendahl's conclusions as they apply to Naval requirements. When it comes to commercial transportation, however, he said that conditions are quite different and are much in favor of the airplane or flying boat. The reasons for this, he indicated, include lower skin-friction, far higher maximum speed, ability to fly in the stratosphere and far lower horsepower for the same carrying capacity.

Other discussers—including President Karl T. Compton and Prof. Emeritus W. Hovgaard of the Massachusetts Institute of Technology, Carl B. Fritsche of Detroit, Neil MacCoull of the Texas Co., who is a Naval Reserve officer with experience in lighter-than-air craft work, and F. W. von Meister of the German Maybach Co.—seemed inclined to agree with Commander Rosendahl in most respects, but they took issue in some cases with Prof. Klemin's conclusion as to the relative merits of airplanes and airships for commercial trans-Atlantic service.

When asked by S. B. Barnard whether a considerable number of smaller rigid airships would not be more feasible for Naval use than one or two larger ones, Commander Rosendahl said that this is often suggested but is not considered feasible because it has not been shown possible to get adequate range or to perform other feats which the larger craft can perform and which are highly desirable from a Naval-defense standpoint.

Safety Symposium Hears Three Papers

● **No. California**

The meeting held Feb. 21 by the Northern California Section at the Athens Club, Oakland, was devoted to the presentation of a Safety Symposium. The dinner attendance was 52; and that at the technical session, 82.

The principal speakers were James Reed, superintendent of the City Ice Co., San Francisco; Prof. L. M. K. Boelter, of the University of California; and Norman Leeds, Jr., of Raybestos-Manhattan, Inc.

25 Years Old

On April 15, 1911, the Society published the first issue of the S.A.E. BULLETIN, predecessor of the S.A.E. JOURNAL. With this issue of the S.A.E. JOURNAL, therefore, the Society begins its twenty-fifth year as publisher of a monthly record of its progress.

Mr. Reed's paper, entitled "Our Accident-Prevention Methods", gave a description of his company's methods in promoting a Safety Campaign among its employes. An abstract of the paper is printed on p. 20 of this issue of the S.A.E. JOURNAL.

The paper by Professor Boelter was on the "Relation of Headlamp Construction to Headlamp Roadway-Performance". It will be found, printed in full, in the June, 1934, S.A.E. JOURNAL, beginning on p. 189.

A digest of the paper by Mr. Leeds—on "Problems in Heavy-Duty Brake-Design and Maintenance"—will be found on p. 20 of this issue of the S.A.E. JOURNAL.

The papers were well received and elicited considerable discussion. A motion picture, "Saving Seconds", was displayed also. It illustrated how much can transpire in the ½ to 1½ seconds of driver-reaction lag that occurs between the time of sighting danger and the time of actual brake-application.

Dinner Dance Draws 205 Guests

● **So. California**

The Ninth Annual Dinner-Dance, during which an eight-act program of novel specialty features was presented, was held March 9 at the Jonathan Club, Los Angeles, by the Southern California Section. The total attendance of members and guests was 205, and dancing continued until an early morning hour.

The special acts by professional performers included artistic and comedy dancing, an accordion "musical cocktail", a comedy team, an acrobatic specialty and novelty juggling.

● **Metropolitan**

Commander Rosendahl knows his heavier-than-air craft also. The picture above shows him about to take off from the deck catapult of the U.S.S. West Virginia during the time he was stationed in that ship.

Lítle Describes Electric Iron

● **Pittsburgh**

The Pittsburgh Section meeting held March 5 was devoted to Electric-Furnace Iron, with Thomas J. Lítle, Jr., past-president of the Society, as principal speaker. Mr. Lítle's description of the processes involved in the manufacture of electric-furnace iron was supplemented and illustrated by a series of lantern slides shown by Mr. Lewis of the Pittsburgh Lectromelt Corp. and a motion picture shown by Mr. Arnold of the American Bridge Co.

The increasing use of electric-furnace iron may be largely attributed to the fact that it can be "made to order", with properties as desired, such as wear resisting, distortion resisting, magnetic, abrasion resisting. In the cupola, temperatures run from 2750 to 2800 deg. fahr.; in the electric furnace, with higher temperatures, much of the carbon goes into solution, giving finer textures and more accurate control.

Ordinary cupola cast irons formerly had tensile strengths of from 15,000 to 20,000 lb. per sq. in., whereas the new electric-furnace irons run from 20,000 to 60,000 lb. per sq. in., in seven general classes. With various alloys, which are easily incorporated in the electric furnace, tensile strengths as high as 100,000 lb. per sq. in. have been attained with moduli of elasticity as high as 24,000,000. Compressive strength runs about 3½ times the tensile strength.

These new properties of cast iron have led to many new uses for this material, which is rapidly replacing other materials in many fields. Cast iron is an ideal material for high-speed machinery, due to its vibration-damping characteristics, and the fact that the strength of the new electric-furnace iron under alternating stresses approaches that of steel. By the use of the electric furnace, the life of castings has been increased from 400 to 900 per cent, using as alloys chromium, silicon and molybdenum.

In large operations, the cupola is used for melting, the electric furnace for superheating—a process known as "duplexing", In smaller heats, "cold" melting is more economical, and has the advantage of making possible the use of small borings and fine scrap without loss by oxidation. Rustless heat-resisting iron may be made by this method. These new irons are replacing cast and forged steels for rolling mills, crushers, crankshafts, cams, brakedrums, housings, and the like.

The pictures shown by Mr. Lewis and Mr. Arnold exhibited actual electric-furnace operations. In addition, an exhibit of electric-furnace-iron castings added interest to the session.

Light Alloys Are Joint Meeting Topic

● **Indiana**

The joint meeting of the Indiana Section with the Indianapolis Chapter of the American Society for Metals held March 11 drew 130 members and guests to the Athenaeum, Indianapolis, to attend the technical session, there having been 58 in attendance at the dinner which preceded it.

A general review of the use of aluminum and magnesium alloys in automotive, aircraft and railcar construction was presented by G. D. Welty, engineer for the Aluminum Co. of America. The title of his paper was "Light-Alloy Employment in Modern Transportation".

Western S. A. E. Groups

Drawing by Gene Guernsey

William B. Stout

Nearly 1600 Members and Guests Hear Speech on the Automobile's Future

Descriptions of Photographs on next page

MEETINGS of the Kansas City, Northern and Southern California, Oregon and Northwest Sections and of the S.A.E. Club of Colorado were addressed recently by William B. Stout, president of the Society, as part of the annual Spring visitation which has for a number of years been among the most important duties of the Society's chief executive. Mr. Stout was accompanied by John A. C. Warner, secretary and general manager of the Society, who also presented an address at each of the meetings. The six formal meetings gathered an audience totaling about 1600 members of the Society and their guests. Additional hundreds were reached through small group meetings arranged by local Section officers in or near the cities where the Section meetings were held.

Mr. Stout's message to all the Sections was substantially the same with the exception of impromptu additions in his inimitable style.

To all of the Sections, Mr. Warner gave a short preview of the history of the Society's activities which will be published in the Thirtieth Anniversary Issue of the S.A.E. JOURNAL in July. In Denver and Portland, where S.A.E. groups have developed specialized safety work, an additional subject was "You and Your Automobile" with special reference to safe operation. Excerpts from addresses by Mr. Stout and Mr. Warner appear under a separate heading. A city-by-city account of the Section meetings where they spoke follows:

March 18 **● Kansas City**

At Kansas City the meeting was arranged and conducted by Chairman S. M. McKee, superintendent and lubricating engineer, Nourse Oil Co. Morris Cohen, F. C. Buchanan and C. A. Shepard, Section officers, assisted. Total attendance at this meeting was about 75.

March 22 **● Denver**

At Denver, Chairman Dean Gillespie, president, Moto Royal Oil Co., introduced past-chairman of the S.A.E. Club of Colorado, most of whom were present at the meeting. Of the 150 men who attended many had driven long distances to be present. Other sidelights on the Denver meeting appear in the group of pictures accompanying this story. Elmer J. Graham, George N. Gromer, F. R. Eberhardt, and Tommy Thompson took a prominent part in the arrangements for the meeting.

March 29 **● So. California**

At Los Angeles, Chairman Tattersfield, president, Electric & Careburetor Engineering Co., introduced the visitors to an audience of about 250. Among the distinguished guests present were, R. L. Daugherty, professor of mechanical engineering at the California Institute of Technology; Dr. Theodor V. Karmair, director of Guggenheim Laboratory for Aeronautics at Pasadena, Calif.; Dr. Margulis, former director of Eiffel Aeradynuwte at Paris, France; R. T. Knapp, assistant professor at the California Institute of Technology; R. M. Mock, Fokker Aircraft Co.; Lieut. A. B. Nicholson, U. S. Army, Fort MacArthur; A. Nischwitz, Fokker Aircraft, Holland; G. F. Peudden, Lockheed Aircraft Corp., Burbank; and Lt. W. M. Duckwitz, engineer accompanying Mr. Stout.

Preeminent among the officers and members who helped with the arrangements were W. E. Powelson, secretary, and F. C. Patton, a past-chairman.

April 4 **● No. California**

Reports on Section activities rendered by J. F. Long of the J. F. Long Co., nominee for chairman, and by other officers opened the meeting in San Francisco at which George H. Mosel, Pacific Coast Manager, Raybestos-Manhattan.

(Story continued on page 32)

Welcome President Stout on Tour

Informal Photographs Show Some of the Men Who Helped With Meetings

(1) President Stout is seen with Walt Disney, creator of Mickey Mouse.

(2) Fred Dundee, manager of the Dundee Auto Repair & Machine Works in Portland, turned out in an old White Model MM, 1910 vintage

(3) W. S. Crowell, secretary of the Northern California Section, rests awhile from the task of helping to arrange a big meeting

(4) Fred R. Eberhardt of Denver at the door of his plant. Mr. Eberhardt, a former member of the Society, has been very active in the S.A.E. Club of Colorado. He helped entertain President Stout and—he's coming back into the Society.

(5) Howard Baxter, Baxter Automotive Service in Oakland, Calif., does a little checking-up while George H. Mosel, Pacific Coast manager, Raybestos-Manhattan, Inc., looks on too

(6) Benjamin Briscoe famous for the old Briscoe automobile was an interested spectator of the Denver proceedings

(7) C. F. Lienesch, technical assistant, director of sales, Union Oil Co. of California, and vice-chairman for aeronautics of the Southern California Section

(8) J. Verne Savage, shop superintendent, City of Portland, Municipal Shop, Portland, and Treasurer of the Oregon Section

(9) Harley Drake, superintendent of Garage, Portland Gas & Coke Co. and chairman of the Oregon Section about to reveal a new idea

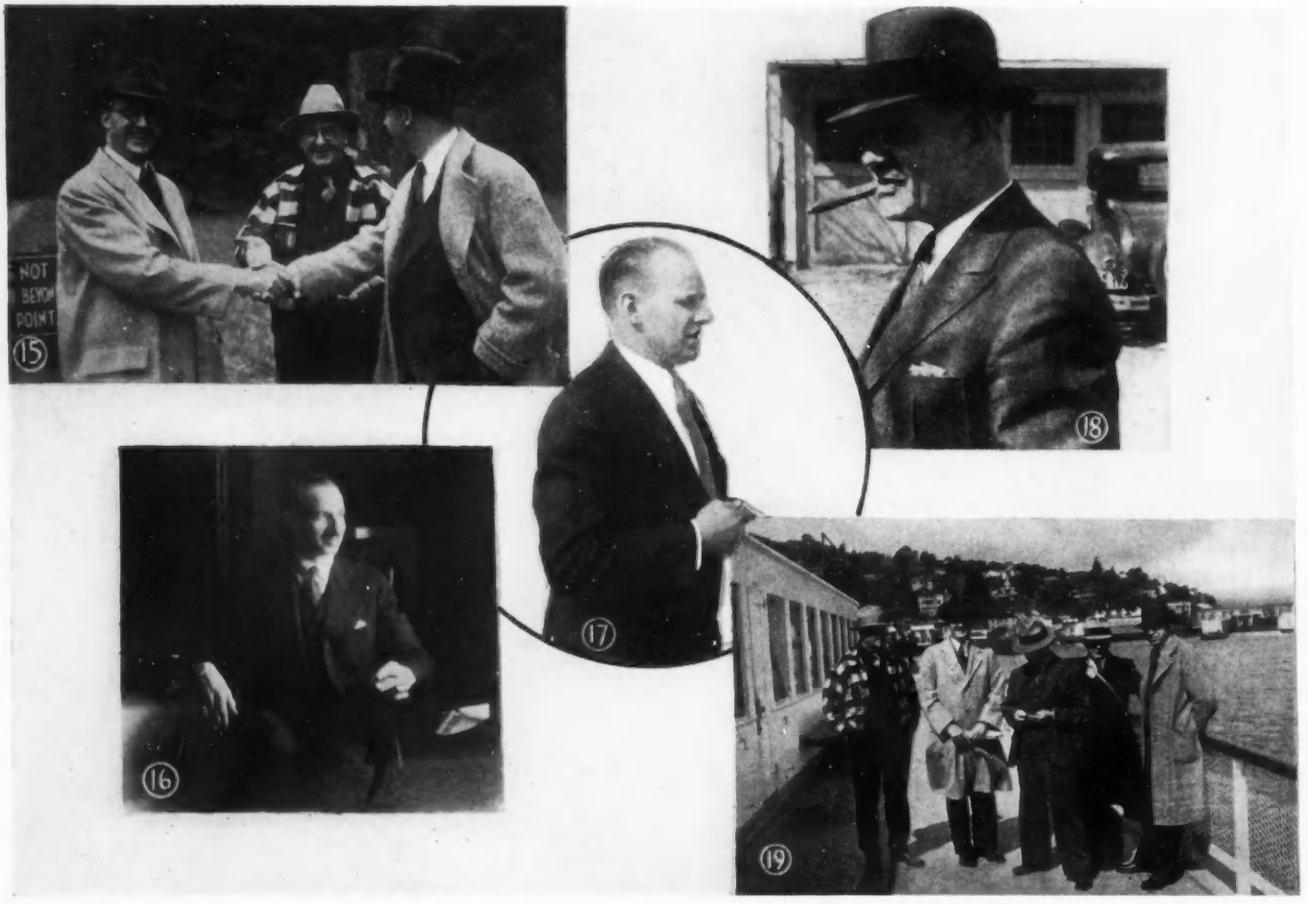
(10) Elmer J. Graham, superintendent, transportation, Public Service Co. of Colorado, with President Stout looks things over from the mountain top.

(11) A colloquy between President Stout and Dean Gillespie, president, Moto Royal Oil Co., who is president of the S.A.E. Club of Colorado this year

(12) President Stout (center) with Messrs. Power, Reinhard, Templin, Jacobsen, Coburn, Powelson, Tattersfield, Grunder, Moore and Patton on the roof of the Jonathan Club, Los Angeles, after a meeting of the governing board of the Southern California Section.

(13) This group taken at the Denver airport includes (standing L. to R.) Elmer J. Graham, superintendent, transportation, Public Service Co. of Colorado; Lieut. H. Montee, Department of Commerce; George N. Gromer, supervisor, motor-vehicles, Mountain States Telephone & Telegraph Co. (sitting L. to R.) Fred Eberhardt, Eberhardt-Denver Co.; Col. Carlos Reavis, head of the Reavis Flying Service; Dean Gillespie, Moto Royal Oil Co.; Tom Shelton, inventor of Shelton Gyro Aeroplane; and William B. Stout

(14) President Stout with Donald Douglas, president, Douglas Aircraft Co., and Harry H. Wetzel, vice-president of the same company



(15) An unusual group. George H. Mosel, present chairman of the Northern California Section, is shaking hands with Joseph F. Long, Joseph F. Long Co., and nominee for the chairmanship in 1935, and Howard Baxter, past-chairman of the Section smiles his approval from the background

(16) George E. Bock, secretary Northwest Section

(17) John G. Holmstrom, chairman Northwest Section

(18) Lou E. Holland, president, Holland Engraving Company, who entertained President Stout and party at Kansas City

(19) A Northern California group on one of the Oakland ferries: (L. to R.) Howard Baxter, George H. Mosel, Sidney B. Shaw, Lt. William M. Duckwitz, engineer accompanying Mr. Stout, and Joseph F. Long, nominee for the Section chairmanship in 1935

Inc., and chairman of the Section presided. Opening remarks were made by Howard Baxter, president, Howard Baxter Automotive Service, with a special introduction for President Stout by Major E. C. Wood, past-chairman of the Section and superintendent of transportation, Pacific Gas & Electric Co. Secretary W. S. Crowell and other officers shared with Chairman Mosel the responsibilities of a very successful event. Attendance at the meeting totaled about 250.

April 10 **● Oregon**

At Portland the whack of Chairman Harley Drake's gavel was heard by nearly 600 members and guests.

Time was found during the Portland visit for Mr. Stout and Mr. Warner to meet with a group of Oregon State College students in mechanical engineering for whom the Section has provided much specialized automotive equipment and help in connection with automotive engineering courses at the college.

Prominent for their work in connection with the meeting were the various officers and committeemen, including J. Verne Savage, shop superintendent, City of Portland, Municipal Shop; Fred Dundee, manager, Dundee Auto Repair & Machine Works; R. W. Mann, manager, Isaacson Iron Works; Mr. Hammond, and numerous others.

April 12 **● Northwest**

At Seattle the meeting was conducted by Chairman John G. Holmstrom, chief engineer, Kenworth Motor Truck Corp., with special entertainment arranged and carried out by Past-Chairman Sherman Bushnell, manager, Automotive Engineering Co. Secretary George Bock was responsible for an elaborate meeting announcement, whereas Howard Reinhart, sales engineer, Ethyl Gasoline Corp., and officers of the Section assisted in various ways with the preparation and conduct of the meeting. A distinguished group of honored guests included C. N. Montieth, chief engineer of the Boeing Airplane Co.

Present World Built On Facts, says Stout

"IF you believe the same things a year from now as you do today—you're slipping." This was the trenchant remark of William B. Stout in summarizing part of his talk on "The Possibilities of the Automobile," which by accretion grew also to be an essay on the possibilities of the automotive engineering mind. Delivered as a presidential address to six S.A.E. Sections in the Middlewest and on the Pacific Coast, the talk emphasized heavily the social consequences of the development of the automobile and other forms of individualized rapid transportation.

The present-day world is built on facts and its future is built on research, Mr. Stout indicated, with the consequence the new devices are produced at an accelerated rate as compared with the time when their genesis was rooted in opinion.

Pioneers in the automotive industry thought

they were designing new cars, new processes, and new types of operation, but what they were really doing was remaking the world by shrinking the map and extending the social radius of mankind. In one generation, he continued, the mechanical operations incident to running an automobile have developed a race of people whose reactions are quicker than those of their ancestors.

A millionaire of 25 years ago could not enjoy the type of fine living available to the poor man today, said Mr. Stout in expressing the belief that the creation of wealth comes from the production of luxuries and that by creating wealth we raise the standard of living. The problem of money is interwoven with all this, said Mr. Stout, and no one knows what money is—least of all the bankers. Money is irrevocably linked to the movement of goods, he indicated, and it is time for the financial engineers to define money if we are to work out some other present and pressing problems. The high rate of obsolescence which affects most of today's industrial products makes it virtually impossible to determine what permanent value is, so that when starting any engineering project it is desirable first to examine the economics involved.

Of automotive engineering, Mr. Stout said that the principles of airplane construction can be adopted profitably by automobile designers to a very large extent. "So far as I know," he said, "no one has ever made a stress analysis of an automobile. We have done too much milk-wagon engineering. An airplane structure must be designed to maintain strength and rigidity under high stress."

In the conventional automobile the chassis has to be so rigid that the strength of the body won't break it. Likewise, the body has to be rigid so that torsion of the frame won't destroy it. With the proper development of stress analysis, he said, "It is possible that the automobile of the future could have a combined frame and chassis that would weigh less than the glass in the windows and that the combined unit would have eight times the strength of the present bodies."

Drake Presents Souvenirs

At Portland, on behalf of the Oregon Section, Chairman Harley Drake presented President Stout and Secretary Warner with souvenirs of their visit in the form of three-dimensional metallic visualizations of the letters "S A E", inscribed with the greetings of the Section.

Warner Views S.A.E. As Powerplant Group

THE first national meeting of the Society of Automobile Engineers had one session and was attended by 32 members, it was pointed out by John A. C. Warner, secretary and general manager of the Society, in his address to West coast sections. By contrast, Mr. Warner continued, in 1935 the Annual Meeting of the Society had 18 sessions and a total attendance at all sessions of 5000 members and guests.

In using the title "Ten S.A.E. Powerplants", Mr. Warner viewed the Society and its efforts as originating from 10 organized sources, the professional activities. He reviewed briefly how some of these activities got under way. Drawing on the archives of the Society for his material, he pointed out, that much of this history would be presented in extended form in the Thirtieth Anniversary Issue of the S.A.E. JOURNAL to be published in July, 1935. When the Society began, Mr. Warner said, it was necessary to determine an exact definition of the word automobile, as that word did not then appear in any of the recognized dictionaries. Again when the Society of Automobile Engineers became "automotive" in character that word, too, was used ahead of the dictionary makers, but this time on a firmer basis because the definition of the word automotive had been established by the tremendous growth of the applications of the internal combustion engine to ways of doing the world's work.

Much of the Society's progress, he indicated, has been a result of the fact that certain men saw red when the words "it can't be done" were flung in their faces. Charles M. Manly was a notable example, he continued. The same spirit which led him to design a radial aircraft engine in the face of scoffers, was instrumental in the early success of the S.A.E.'s aircraft work in which Mr. Manly had a large part.

Almost every professional activity of the S.A.E. represented at its inception a kind of prophecy, because the beginnings were often made before the world had waked up to the fact that such a profession had been born. Mr. Warner traced in detail the growth of the professional activities, pointing out that each of them resulted in a continuous and logical progress for the Society.

To the Pacific Coast Sections of the Society, he said that the automotive industry in all its branches has gained much from the men in the industry on the Pacific Coast. "The progressive spirit out here is very much in tune with the natural tempo of automotive enterprise", he said.

Reinhart Links Fuels, Combustion

● **Northwest**

Illustrating his paper by lantern slides and by demonstrations on a portable engine-dynamometer set, Howard A. Reinhart, of the Ethyl Gasoline Corp., Seattle, aroused a keen interest among the 61 members and guests attending the regular meeting of the Northwest Section held at the New Washington Hotel, Seattle, on March 15, 1935. An abstract of the paper is printed in the S.A.E. JOURNAL, May, 1935, on page 21.

Mr. Reinhart, in his paper, introduced the subject of fuels and their combustion, and then proceeded to enlarge on the subject of detonation and the suppression of detonation. Drawing an analogy between detonation and electricity on grounds that no definition of either is known, he enumerated certain characteristics of detonation. It is a function of: (*a*) the pressure at which the mixture is burned, (*b*) the initial temperature of the charge, (*c*) the chemical constitution of the fuel, (*d*) the air-fuel ratio of the mixture, and (*e*) the time of ignition with relation to piston position.

Tetraethyl-lead, among other chemicals, was found to suppress detonation effectively; but, if used alone, lead oxide would form. To eliminate and counteract this harmful result ethyl fluid contains, in addition to tetraethyl-lead, ethylene dibromide and ethylene dichloride, both of which have greater affinity for lead than for oxygen during combustion. Two lead salts are formed—lead bromide and lead chloride—which pass out of the exhaust in a vaporous state leaving no deposits or harmful effects inside the cylinder.

Along with detonation, high-compression gives rise to roughness in engines. Cylinder-head design is of prime importance to reduce detonation, but more especially to reduce roughness. Spark-plug and valve locations are important contributing factors.

After discussing the theory of the Otto cycle and pointing out the inadvisability of retarding ignition and valve timing and of restraining the induction system (all of which expedients having been applied to suppress detonation at a loss of output) Mr. Reinhart briefly discussed supercharging and then launched into the practical aspects of his subject. He prefaced the second part of his paper by a rapid statistical survey. From 1925 to 1935 the following increases were accomplished:

(1) Maximum power, 90 per cent;
(2) Power per unit volume, 64 per cent;
(3) Compression pressure, 46 per cent;
(4) Compression ratio, 30 per cent;
(5) Engine speed at maximum power, 30 per cent;
(6) Mean effective pressure at maximum power, 26 per cent; while displacement has increased only 15 per cent.

Racing engines were discussed next, and then gasoline mileage was taken up. The author reminded the audience that the lack of improvement in gasoline mileage was not due to lack of increased engine efficiency but to better roads which allow faster average speeds with consequent increases of resistance, which varies as the square of the speed. The American public thinks of itself as being economical; in reality, it is anything but economical. Every improvement made in the efficiency of the gasoline engine has been used in additional power and performance, with the economy line remaining constant. For 85 per cent of the time, an average car engine is used only at from 10 to 45 per cent of its capacity.

Said Mr. Reinhart: "Just as the pendulum has swung to the extreme of performance, so will it swing to the side of economy. When this time arrives the power curve will drop, but a much greater drop will be shown in displacement; and, instead of the economy curve remaining flat, as it has been for so many years, it will show a very decided decline. In other words, instead of getting 14 or 15 miles per gal., we will probably be getting 22 to 23 miles per gal."

Mr. Reinhart enumerated some difficulties encountered in the design and construction of high-output engines. Increased bearing pressures, increased inertia, manifold difficulties, valve-spring surge, special-alloy valves, special spark-plugs, and other features, were commented upon by the author and later by several discussers.

In conclusion Mr. Reinhart predicted that "with the gradual improvement in metallurgy, design improvement based upon better knowledge of flame propagation and the better understanding and use of instrumentation in the field will greatly add to the efficiency of the Otto cycle. Furthermore, with the radical, fundamental changes, such as solid injection and the possibilities of a variable-compression engine controlled by mean effective pressure, who knows but that the race between the Otto cycle and the Diesel cycle will still be won by the former, since it has been definitely proven in the laboratory that the Otto cycle, from a thermal-efficiency standpoint, is more efficient than the Diesel cycle."

Section Spotlights Knock-Rating Data

● **Baltimore**

The meeting of the Baltimore Section held at the Engineers Club, Baltimore, on April 10, was attended by 44 members and guests, 28 of whom had participated in the dinner which preceded it. The occasion was termed "Knock-Rating Night".

The speakers were H. K. Cummings, chief of the automotive powerplants section of the National Bureau of Standards, and Clarence S. Bruce, assistant mechanical engineer of the Bureau.

Motion pictures of the 1934 Cooperative Fuel Research Committee road tests held at Uniontown, Pa., were shown. These were described by Mr. Bruce, who talked also on the problems encountered by the C.F.R. Committee.

Mr. Cummings discussed new developments in gasoline knock-rating, and also outlined the general history of the C.F.R. Engine and its development.

The Section went on record at the meeting as being opposed to any diversion of taxes collected for the motor-vehicle fund of the State of Maryland to any purpose other than the construction and maintenance of highways.

Winchester Tells Of Syrian Operation

● **New England**

The New England Section's April 9 meeting was held at the Massachusetts Institute of Technology, Cambridge, Mass., the paper being presented by J. F. Winchester, manager, automotive department, Standard Oil Co. of New Jersey. It was entitled "Operation and Maintenance" and included an illustrated description of the construction of an oil pipe-line across the Syrian desert with special reference to how the motor-vehicles employed were selected, operated and maintained. At the technical session, 186 members and guests were present, 48 having attended the dinner which preceded it.

Mr. Winchester pointed out that successful operation depends upon selecting the vehicles best suited for particular jobs. Unnecessary difficulties face the operator who does not balance all the engineering factors in a given truck operation. Well balanced results follow the study of all factors.

Sparrow Augments His Bearing Data

● **Philadelphia**

At least 125 members and guests attended the April 10 meeting of the Philadelphia Section to hear S. W. Sparrow, of the Studebaker Corp., discuss "New Developments in Engine Bearings". Charles O. Guernsey, chief engineer, J. G. Brill Co., presided. Twenty-eight attended the dinner which preceded the technical session.

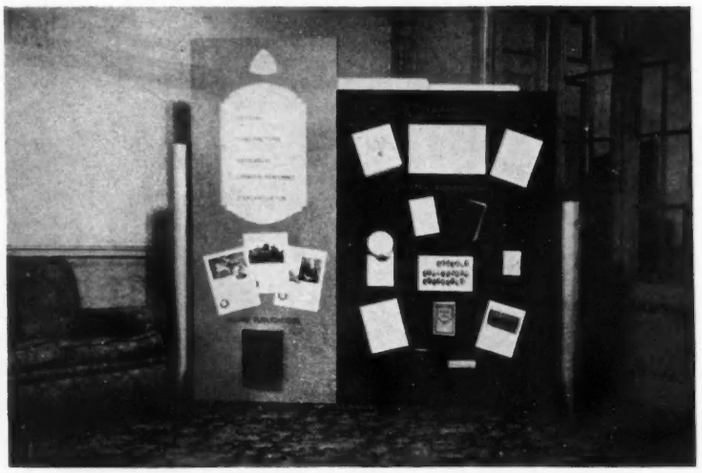
Mr. Sparrow reviewed some of the work he presented at the 1934 Semi-Annual Meeting, as well as considering many additional data of considerable interest that have been obtained since that time. The 1934 paper was printed in the S.A.E. JOURNAL, July, 1934, p. 229.

After outlining the comparative performance of babbitt and copper-lead bearings under sustained high-speed operation, Mr. Sparrow discussed in some detail the cracking of the babbitt bearing and the tendency to blister of the copper-lead bearing.

Considerable interest was displayed in the desirable thickness of the shell and thickness of the bearing metal. Mr. Sparrow reported best results with a shell of approximately 0.050-in. thickness with a minimum thickness of babbitt of 0.015 in., or a thickness of the copper-lead of about 0.015 in. In cases of failure of both types, it was found that usually the shaft was more seriously damaged with the babbitt bearings than when the copper-lead bearings were used.

Among those who engaged in the discussion of the paper were J. P. Stewart, of the Socony-Vacuum Corp.; R. W. A. Brewer, consulting engineer; D. D. Robertson, of the Wilkening Mfg. Co.; and F. D. Hubley, of the Autocar Co.

Cleveland Uses Effective Display



GUESTS at Cleveland Section meetings have taken kindly to the silent demonstrator of the advantages of membership in the S.A.E. provided for them by the Membership Committee of the Section, Hoy Stevens, chairman. The scene is the lobby of the meeting room of the Section in the Cleveland Club. At the bottom of the display panel on the right of the picture is a pocket containing applications for Society membership, many of which have been removed by prospective members without further solicitation.

The display shows a comprehensive group of material. At the top left is a brief statement of the functions of the Society. The Society's publications are mounted in such a way that they can be "sampled". A selection of interesting pages from the S.A.E. JOURNAL, preprints, advertisements, and membership leaflets emanating from headquarters all have a place.

Conference Attendance Rises

As one of the contributors to the Sixth Annual Greater New York Safety Conference (see note page 22, April issue of the S.A.E. JOURNAL) the Society has been notified officially that attendance at the Conference was 61 per cent greater than at the sessions last year.

S.A.E. Membership

Membership in the automotive engineers' own engineering society automatically provides a man with a prestige and standing in his profession, the value of which cannot be over-estimated.

Three Aviation Papers Presented at Chicago

● **Chicago**

The Chicago Section held its April 2 meeting in the Hamilton Club, Chicago, and three papers were presented. The dinner attendance was 116; and that at the technical session, 181.

"Night Flying—Then, and Now" was the subject presented by "Jack" Knight, a pilot for United Air Lines.

P. A. Wright, of United Air Lines, read a paper entitled "This Business of Aviation".

The title of the paper by R. F. Norris was "Acoustics of the Airplane".

M.I.T. Branch Meets

Two important meetings were held recently by the Student Branch of the Society located at the Massachusetts Institute of Technology, Cambridge, the first being in conjunction with the A.S.M.E. and open to members only. This meeting was to welcome three new members of the mechanical engineering staff of the Institute. These were Professors Wilkes, Keenan, and LaForrest. The meeting held Feb. 26 was an open meeting attended by well over a hundred persons. At this meeting J. L. Carroll of the Hemphill Diesel Engineering Schools and David Evans, holder of the world's speed record for Diesel-powered racing cars, lectured on Diesel power and showed motion pictures connected with this subject.

Fleet Maintenance Covered by Churchill

● **Northwest**

A meeting of unusual interest was held by the Northwest Section, Feb. 15, at the New Washington Hotel, Seattle. W. W. Churchill, superintendent of equipment of the Washington Motor Coach Co., one of the largest highway-transport organizations of the Northwest, gave a paper on "Fleet Maintenance". The dinner attendance was 31; and that at the technical session, 46.

A maintenance program is predicated on a study and consideration of the service to be rendered, the type of equipment used, and the road and weather conditions. Lubrication, inspection, maintenance, and cost recording were the sub-headings under which Mr. Churchill discussed many pertinent details, of which the highlights are as follows:

Lubrication is planned and carried out on a mileage or daily basis, and complete records are kept. The motor oil must be given considerable thought regarding the correct grade for the particular service. In this part of the country, for example, summer temperatures reach over 100 deg., while in winter a temperature of 40 deg. below zero may occur. Analyzing the drainings at different periods is advisable to determine the most advantageous draining periods and the correct grade of oil for use in the various motors. Greasers should be selected and employed with care; they can be trained to make inspections concurrently with lubrication.

Proper education of personnel is important for many good reasons. It is the best method of securing accurate reports from operators. They are instructed, for example, to report the actions and defects of units and not to write down what repairs they deem should be made. In this manner are avoided such difficulties as the operator reporting, "grind valves", when in reality the trouble might have been merely a defective plug.

Most important to proper maintenance are inspections with modern testing equipment, skilled specialists, regular routine, and comprehensive report forms. Mr. Churchill appended to his paper reproductions of inspection cards used in his shops. They are divided on a mileage basis into five groups. Group *A*, 2000 miles, includes, briefly, such inspection items as air cleaners, plugs, distributors, steering systems, and brakes; Group *B*, 5000 miles—oil filters, valves, gasoline and oil lines, cooling system, electrical system, driveshafts, springs, and bodies; Group *C*, 15,000 miles—fuel pumps and the lubrication of gears; Group *D*, 30,000 miles—compressor chains, motor supports, air connections, and wheels; Group *E*, 60,000 miles—pistons, motor bearings, transmissions, differentials, and the grinding of valves.

As new equipment is placed in service or older equipment is modernized changes may be made in the mileages between inspections. In case of recurring trouble or failures in particular items, the corresponding inspection mileage intervals are immediately shortened until corrections are established. For example, on one type of equipment, failures in ring gears and pinions occurred after about 100,000 to 125,000 miles. Since the tooth wear on pinions is much greater than on ring gears, an order was enacted to replace pinions only at 100,000-mile intervals. The trouble was eliminated immediately. Contrary to some manufacturers' demands to install matched gears and pinions, the practice of replacing only pinions proved successful for three years and resulted in ring-gear life of 300,000 miles.

Among parts which should be installed in duplicate Mr. Churchill cites gasoline supply pumps, coils, and condensers. These should be so connected that only one of each operates regularly and the other is reserved for emergency, when the spare unit should become operable by a mere turn of a switch. Air brakes have caused very little difficulty. With proper modernization and overhauls the life of a good chassis is long. Mr. Churchill estimates that many Northwest chassis have operated in excess of 750,000 miles. Among the modernizing features are streamlined bodies which are gaining popularity because of their appeal to passengers and their economy. Of the bodies in the Northwest, 75 per cent are of all-steel construction. Weather conditions cause dry rot of wood; bodies built of wood require complete overhauls every three years. Aluminum was not favored until recently, when improvements in its alloys made it more resistant to salt air. Owing to the tremendous saving in weight, aluminum-alloy bodies are now coming into their own.

As a guide to purchases of new units, a complete cost record of material and labor is kept, itemized to cover separately the engine, chassis, transmission, differential, body, electrical system, and accidents. This apparently tremendous task is so well organized that the compilation of these data on ninety units of equipment is performed regularly by one clerk.

The paper aroused widespread discussion among the members and guests present. No less than ninety separate discussions resulted. The center of interest was the engine, with valves and valve seats, especially those of the inserted type, attracting particular attention.

N. Y. U. Group Meets

Talking pictures of an airplane trip through South America were presented to a group of forty-five New York University students and their guests from the Webb Institute of Naval Architecture by D. M. Parker, a representative of Pan-American Airways, at a smoker on March 6. The pictures left clear impressions of the beautiful cities and scenic grandeurs along the far-flung Pan-American routes. An open discussion followed, and the evening was concluded with refreshments.

Applications at Peak

Names of 66 new applicants for membership in the Society are printed in this issue of the S.A.E. JOURNAL. In calling the attention of all members to the desirability of acquainting themselves with the monthly report of applicants and members qualified, the Membership Department points out that the number of applicants printed this month exceeds the figures for a single month in any recent year.

A Member Says:

We often get some news through the S.A.E. long before the information is put into practice, and we can predict in that way what may come. A number of things that have been proposed in the last two or three years may be adopted; in fact, there is definite evidence that several of them are coming very rapidly.

Janeway Presents "Humanized" Work

● **Dayton**

The paper presented at the March 14 meeting of the Dayton Section in the Engineers Club, Dayton, was by R. N. Janeway, research engineer, Chrysler Corp., Detroit. Its title was "Humanized Automotive Engineering". The attendance was 25 members and guests, extreme interest being shown. A dinner preceded the technical session.

The author covered proper distribution of car weight, location of the center of percussion to secure maximum riding comfort and limitation of low-frequency noises in the car which, together with the higher harmonics of these tones, cause passenger fatigue. After presentation, the paper was discussed.

Patch Acts as Treasurer

E. S. Patch, vice-president, Moraine Products Division, General Motors Corp., will act as treasurer of the Dayton Section for the remainder of the Section year to fill the vacancy caused by the recent death of Charles L. Lee. Mr. Patch is the Section's nominee for treasurer in 1936.

Regional Meeting Held at Ithaca

● **Syracuse**

The April 9 meeting of the Syracuse Section was held at Cornell University, Ithaca, N. Y., as a regional meeting. Forty-two members and guests attended the dinner and the technical session. The paper presented was by Prof. George Burr Upton and was entitled "Essentials of Riding Comfort".

West Discusses Metals Subjects

● **Buffalo**

The Buffalo Section held its April 9 meeting in the Statler Hotel, Buffalo, the dinner attendance being 32 and the total attendance at the technical session, 62. The subject chosen by C. L. West, sales and research engineer for the Electric Furnace Co., Salem, Ohio, was "The Practical and Economic Application of Special Atmospheres in the Heat Treatment and Brazing of Metals". Prominent discussers were C. F. Lautz, W. R. Ramsaur and Mr. Van Mater.

C.S.U. Meeting Draws 100

The Student Branch at Ohio State University held a meeting March 1 at which the total attendance was 100 members and guests. The subject, "Engineering Research", was treated by Prof. J. J. Caton, director of the Chrysler Institute of Engineering. Some of the subjects he considered were the careful selection of engineers with regard to personality, "misfits", and brief outlines of the careers of outstanding men who have had no college training. In his opinion, mastery of the English language is necessary and is an important adjunct to success.

Advertising & Service Share Long Program

● **Oregon**

The main thing about advertising is to advertise, was the thought stressed by C. L. Baum, promotion manager for the *Oregon Journal*, in a talk on "Advertising and Business" at the March meeting of the Oregon Section held at Lloyd's Clubhouse the evening of March 8.

"Advertising and sales promotion can and will never be an exact science", Mr. Baum stated in opening his talk. "Opinions of self-styled critics as to whether an advertising or sales idea is good or bad often means very little; the only certain test as to good or bad being: Does it bring the business?" It was pointed out that often the most direct method of advertising a certain product of service would defeat its own purpose unless backed up with advertising through other media.

That the new-car dealer's service shop has changed from being considered a necessary evil in 1928 to being a profit-making department now was shown by K. H. Mutch, service manager of Wentworth & Irwin, Nash division, in his talk on "Service That Appeals to the Customer".

"Machinery for trouble shooting is now available to the service department which will actually show the customer the fault with his engine even though he is not a mechanic", said Mr. Mutch. "The machine, though, is no better than the man operating it; so, it is important to hire competent help. If the service department is kept clean and up-to-date and operates on the policy of doing its best by each customer, there is no reason for the department not showing a profit."

A "voltage regulator" was defined by Howard A. Morse, service manager of Tracey & Co., as an automatic device which controls the output of the generator from minimum to maximum inversely to the charged condition of the storage battery. The device to be practical must be sensitive to one-tenth volt. Mr. Morse demonstrated the Leece-Neville voltage regulator for passenger cars, and explained its value to present-day car-owners.

New Day in Flying Is Washington Topic

● **Washington**

Two papers were presented at the April 1 meeting of the Washington Section held in the University Club, Washington, there having been a preceding dinner which 14 members and guests attended and an audience of 97 at the technical session.

The paper by Agnew E. Larsen, of the Autogiro Co. of America, was entitled "The Future of the Autogiro for the Private Flyer". An abstract of the paper is printed on page 22 of this issue of the S.A.E. JOURNAL.

The title of the paper by Walter T. Brownell, aeronautics development engineer for the Bureau of Air Commerce, was "New Plane Developments for the Private Flyer". He exhibited and described models of various types of aircraft for the private flyer, the development of which is being sponsored by the Bureau. Among these is the "Hammond Y", a safety development, and a new automobile-engine-powered aircraft which will come under the low-price classification.

Regional Meetings Planned

● **South Bend**

A regional meeting of the Society was planned for South Bend, Ind., on April 24, under the auspices of the Chicago section, R. E. Wilkin, chairman. Members of the Chicago, Indiana, and Detroit Sections, as well as individual S.A.E. members in the South Bend area were to be especially invited.

● **Hartford**

The second regional meeting to be held in Hartford, Conn., was planned for April 26, under the direction of C. H. Chatfield, vice-president of the Society representing Aircraft Engineering.

● **Oshawa**

Under sponsorship of the Canadian Section, J. C. Armer, chairman, a regional meeting is to be held in Oshawa, Ont., May 15.

It is proposed to hold additional regional meetings in Sunnyvale, Calif. (sponsored jointly by the Northern and Southern California Sections), and in Minneapolis, Minn. (sponsored by the Milwaukee Section). Anyone interested in attending either of these meetings should communicate with one of the Sections concerned.

There is under discussion a regional meeting of the Society which it is proposed to hold in Atlanta, Ga.

It will be appreciated by the headquarters staff in New York if anyone in a position to assist with or be present at such a meeting will communicate with the assistant general manager so that the information may be passed on to the Meetings Committee of the Society.

Scenes from Oregon Meeting

(*At right*) Section officers and guests at the April 10 meeting of the Oregon Section.

Left to right, front row: S. H. Graf, Oregon State College; John A. C. Warner, general manager, S.A.E.; H. W. Drake, chairman, Oregon Section S.A.E.; William B. Stout, president, S.A.E.; George W. Peavy, president, Oregon State College; Douglas McKay, president, Oregon Auto Dealers Association; John Holmstrom, chairman, Northwest Section S.A.E.; J. Verne Savage, treasurer, Oregon Section S.A.E.

Rear row: William Paul, Oregon State College; Robert Mann, past-chairman, Oregon Section S.A.E.; A. A. Knowlton, Reed College; James Cassell, editor, *Automotive News*; Lt. W. M. Duckwitz, engineer, Stout Laboratories; Ole Berg, Jr., Union Oil Co.; M. E. Van de Water, Refining Industries, Inc.; R. G. Ott, president, Portland Wholesalers Association; Axel Kildahl, president, Portland Automotive Trades Association; S. C. Schwartz, chief chemist, Portland Gas & Coke Co.; S. R. Hammond, *Trade Lanes*; Prof. Walter Jones, Oregon State College.

Continued in right-hand column

(*At left*) Part of the crowd of more than 500 persons which turned out to hear President Stout at the April 10 meeting of the Oregon Section.

MORE THAN A *Million People* OWN OR OPERATE THE BELL SYSTEM

The Bell System furnishes a nation-wide telephone service to a great and populous country—a service used for 59,000,000 talks a day. Telephone conversations per capita in this country are more than nine times as many as in Europe.

It takes 275,000 trained people to build and operate the switchboards, wires, cables, and other apparatus that make this service possible. It has taken the savings of 850,000 people to pay for the plant and equipment of the Bell System. Six hundred and seventy-five thousand own stock in the American Telephone and Telegraph Company, and in many instances other Bell securities. Another 175,000 own Bell System bonds or stock in the operating telephone companies. This invested money is the result of work and thrift. No other business organization is so widely owned by so many people.

It is owned by the people, and it is run by wage-earning men and women. Their incentive is pride in performance; in doing a good job come recognition and promotion.

Since its beginning more than 50 years ago, the Bell System has rendered a constantly improving service more and more indispensable. Usefulness to the public is the motive that keeps the telephone business going. In the true sense of the word, this is a democracy in business.

More than half the stockholders of the American Telephone and Telegraph Company, the parent company in the Bell System, are women. Nobody owns as much as one per cent of the stock.

BELL TELEPHONE SYSTEM

"STURACO"
★★★★
EXTREME PRESSURE ("E.P.")
GEAR AND CHASSIS LUBRICANTS

FLEET OPERATORS

experiencing frequent parts replacement resulting from

OVERLOADING

SUSTAINED HIGH DRIVING SPEEDS

SHOCK LOADS

RAPID ACCELERATION

HIGH AXLE AND TRANSMISSION TEMPERATURES

may well investigate the proved economy of this time-tested, high recommended FULL "EP" gear lubricant.

Write today for copy of No. 4 Engineering Bulletin

"STURACO" E. P. LUBRICANTS ARE THE ORIGINAL DEVELOPMENT OF
D. A. STUART & CO.
ESTABLISHED 1865
GENERAL OFFICES, 2727-2753 SO. TROY ST. CHICAGO, U.S.A.
BRANCHES IN PRINCIPAL CITIES

Notes and Reviews

THESE items, which are prepared by the Research Department, give brief descriptions of technical books and articles on automotive subjects. As a rule no attempt is made to give an exhaustive review, the purpose being to indicate what of special interest to the automotive industry has been published.

The letters and numbers in brackets following the titles classify the articles into the following divisions and subdivisions: *Divisions*—A, Aircraft; B, Body; C, Chassis Parts; D, Education; E, Engines; F, Highways; G. Material; H, Miscellaneous; I, Motorboat; J, Motorcoach; K, Motor-Truck; L, Passenger Car; M, Tractor. *Subdivisions*—1, Design and Research; 2, Maintenance and Service; 3, Miscellaneous; 4, Operation; 5, Production; 6, Sales.

AIRCRAFT

The Aerodynamic Forces and Moments on a Spinning Model of the F4B-2 Airplane as Measured by the Spinning Balance

By M. J. Bamber and C. H. Zimmerman. N.A.C.A. Technical Note No. 517, February, 1935; 11 pp., 11 figs. [A-1]

A New Method for Calculating the Climbing Speeds of Aeroplanes of Great Climbing Capacity

By G. Otten. Published in *The Journal of The Royal Aeronautical Society*, February, 1935, p. 133. [A-1]

The author points out that while several methods for calculation of the climbing speeds of airplanes are in use it is well known that they do not yield quite accurate results when applied to machines with great climbing capacities, and thereby give rise to inaccuracies which become of greater importance with increasing climbing capacity of the plane.

With the aid of the method described in the paper, it is said to be possible, by making use of the exact normal information, to determine the climbing speed of every airplane with great accuracy and without materially increasing the amount of work involved.

Results from the Compressed Air Tunnel

By Ernest F. Relf. Published in *The Journal of The Royal Aeronautical Society*, January, 1935, p. 1. [A-1]

The author while pointing out that there are not as yet sufficient data to enable it to be said that the Compressed Air Tunnel is an infallible guide to full scale conditions, from the evidence which at present exists it appears exceedingly unlikely that any serious discrepancies will be found.

The Aerodynamic Aspect of Wing-Fuselage Fillets

B. H. Muttray. Translated from *Luftfahrtforschung*, Vol. 11, No. 5, October 25, 1934; Verlag von R. Oldenbourg, München und Berlin. N.A.C.A. Technical Memorandum No. 764, February, 1935; 12 pp., 30 figs. [A-1]

The 1934 Contest for the Deutsch De La Meurthe Trophy

By Pierra Léglise. Translated from *L'Aéronautique*, July, 1934. N.A.C.A. Technical Memorandum No. 765, February, 1935; 43 pp., 44 figs. [A-1]

Effect of Aerodynamic Design on Glider Performance

By A. Lippisch. Translated from *Luftfahrtforschung*, Vol. II, No. 5, October 25, 1934. N.A.C.A. Technical Memorandum No. 762, January, 1935; 10 pp., 21 figs. [A-1]

Limites d'Emploi du Matériel Volant et Facteurs de Charge

Published in *L'Aéronautique*, February, 1935, L'Aérotechnique section, p. 13. [A-1]

A method of calculating load factors is proposed in which shall be taken into consideration the effect of squalls, the effect of control action during squalls and the effect of all possible aileron settings instead of only three flight conditions. In addition, certain limitations on the use of an aircraft, in accordance with its type, are suggested.

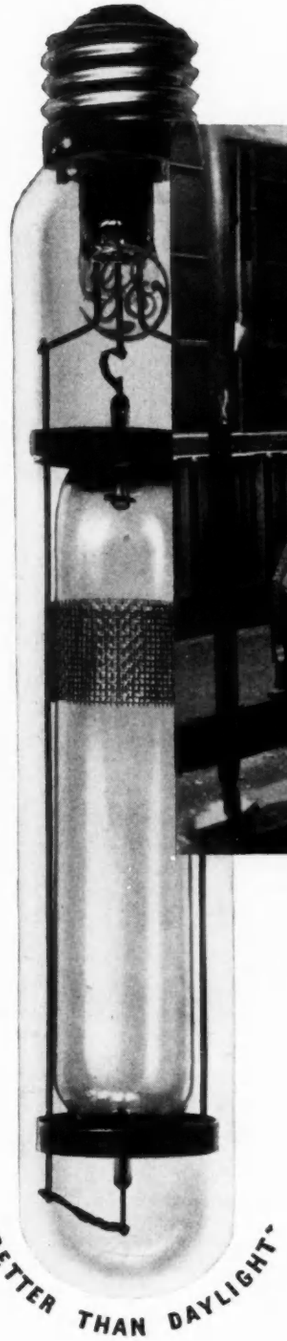
Les Hélices Aériennes

By M. Warnier. Published in *Revue Général de l'Aéronautique*, No. 17, p. 24. [A-1]

Two fatal accidents due to breakage in flight of metal propeller blades indicate the need for further study of problems in connection

(Continued on page 40)

"Now BETTER LIGHT INSIDE THE BODY THAN WE EVER HAD OUTSIDE"



Higher levels of glareless light with greater uniformity over the entire body. Note the detail visible even within the body under G. E. High Intensity Mercury Vapor Light

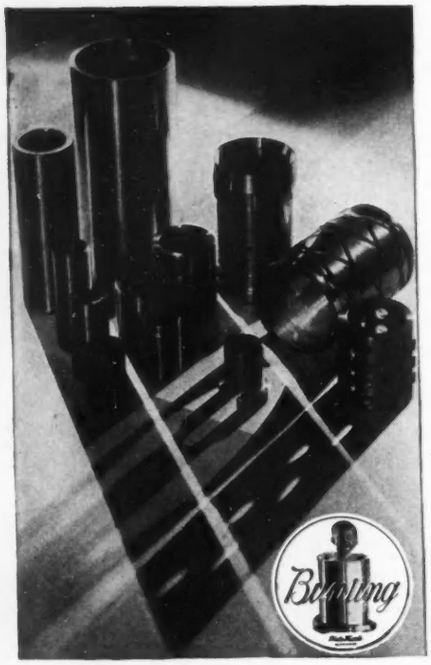
Body lighting for easier, faster production moves into a new era with G. E. High Intensity Mercury Vapor Lamps. With this highly efficient modern light, the lamps are placed a foot farther back and a foot higher as well as being spaced almost twice as far apart along the conveyor than was possible with former lighting. Fewer lamps, more head room, less heat and — here is the important item — much more light, of a more penetrating and detail-revealing quality with intensities uniform to a greater degree over the entire body. Even the inside of the body is illuminated to such an extent that one automotive engineer said: "We get more light inside the body than we had on the outside."

There is no glare from the day-light sensation which these High Intensity Vapor Lamps produce. Detail on the working surfaces stands out in bold relief, as though magnified. The finest scratch is clearly visible and the slightest variation in color shading is immediately noticed. Not only do workers see better, with a minimum of eye fatigue, but with a greater degree of safety. The management profits through a better quality of work and a reduction of loss by spoilage.

Details concerning this modern industrial light, which is being adopted by leaders in industry, are yours for the asking. General Electric Vapor Lamp Company, 803 Adams Street, Hoboken, New Jersey.

GENERAL ELECTRIC VAPOR LAMP COMPANY

630 Copr. 1934, General Electric Vapor Lamp Co.



BECAUSE this company provides for all automotive industries a capable and intensively specialized service relating to the metallurgy, design, and application of important automobile parts made of bronze alloys, many manufacturers have come to look upon The Bunting Brass & Bronze Company as, in some respects, a part of their own organizations, especially in the making up of specifications.

The fruits of constant research conducted by our engineers and metallurgists—facts not readily obtainable anywhere else—are offered freely to all and without any obligation to make use of the ultra-modern manufacturing departments created here for economical and accurate production. Can we help you?

THE BUNTING BRASS & BRONZE COMPANY, TOLEDO, OHIO

Branches and Warehouses in All Principal Cities

BUNTING Quality

PHOSPHOR·BRONZE

BUSHINGS · BEARINGS

MACHINED AND CENTERED BRONZE BARS

NOTES AND REVIEWS

Continued

with such propellers, the author says. The present lengthy exposition treats one aspect of this question, the checking by calculation of the strength of a propeller blade. The method is explained, the results examined critically, and practical examples of its application given.

Some Problems Connected with a Stratosphere Ascension

By Jean and Jeannette Piccard. Published in *Industrial and Engineering Chemistry*, February, 1935, p. 122. [A-4]

The authors emphasize that the organization of a stratosphere flight is not essentially a problem for the free balloon pilot, but rather a problem for the engineer and especially for the chemical engineer. The difficulties are said to be similar to those met daily in the laboratory and in the factory; these include: air-conditioning, method of releasing ropes and ballast, installation of valve rope, and gondola construction.

Investigation of the Accident to the Flying-boat J-BCDO, "Sirohato."

Report of the Accident Investigation Committee. Report No. 116 of the Aeronautical Research Institute, Tokyo Imperial University; January, 1935; 243 pp., abstracted in English. [A-4]

La Vitesse Critique de Torsion des Ailes et la Vitesse d'Inversion des Ailerons

By M. Vellay. Published in *Revue Général de l'Aéronautique*, No. 17, p. 131. [A-4]

Above certain speeds, two phenomena are manifested in aircraft wing structures, the author explains:
(a) The wing truss structure becomes unstable and the deformation due to torsion increases and causes wing breakage and
(b) The rolling moment of the aileron is annulled by the wing deformation.

In this article, it is proposed to determine these critical speeds for any wing or aileron. The results of the Lanchester-Prandtl theory are used in the calculations.

BODY

Modern Steel Motor-Car Body Building

By G. L. Kelley. Published in *The Institution of Automobile Engineers Journal*, February, 1935, p. 15. [B-1]

This article reviews the factors which have resulted in improvement in steel bodies, and which have contributed to their lowered cost of manufacture.

CHASSIS PARTS

Relations entre la Suspension des Voitures et Leur Mouvement de Galop

By Y. Rocard. Published in *Le Génie Civil*, Jan. 12, p. 38 and Jan. 19, 1935, p. 56. [C-1]

Taking into account the progress already made in the study of front-end gallop, the author believes it possible to define more exactly the movement of vehicles during gallop, and not merely its characteristic periods, to determine more accurately the nature and effect of damping and to draw from such a study more precise conclusions as to desirable car weight distribution, suspension design and shock absorption. This article aims to attain these ends.

Betrachtungen über Fahrzeugrahmen

By Oskar Diesel. Published in *Automobiltechnische Zeitschrift*, Jan. 10, 1935, p. 1. [C-1]

In his notes on frames, the author covers the following topics: function of frames; how rigidity is secured; design of frame members; strength of sheet metal; butt straps; rivets or welding; tension areas, measures of elongation and strength calculations.

Concours pour la Création de Dispositifs de Démarrage dans la Neige ou sur Sol Glissant

By Henri Petit. Published in *La Vie Automobile*, Feb. 25, 1935, p. 73. [C-1]

A unique competition is here described, one to determine the relative efficacy of various methods of securing and maintaining traction on snowy and icy surfaces. A description is given of the 13 devices entered and of their performance, and their merits are evaluated.

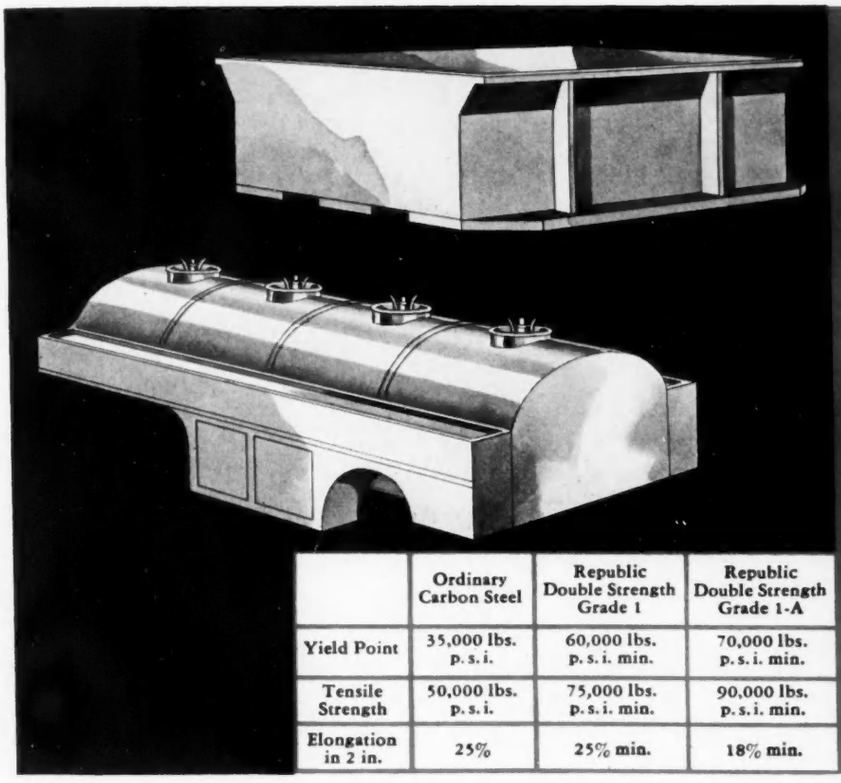
Zubehör, Werkstoffe und Konstruktionsteile auf der IAMA

Published in *Automobiltechnische Zeitschrift*, March 10, 1935, p. 124. [C-1]

A description is given of the most notable exhibits of accessories, materials and parts in the recent Berlin show.

(Continued on page 42)

Designing Engineers . . . save weight without sacrificing strength



MAKE *one* POUND OF STEEL DO THE WORK OF *two* WITH

REPUBLIC *Double Strength* STEELS

	Ordinary Carbon Steel	Republic Double Strength Grade 1	Republic Double Strength Grade 1-A
Yield Point	35,000 lbs. p. s. i.	60,000 lbs. p. s. i. min.	70,000 lbs. p. s. i. min.
Tensile Strength	50,000 lbs. p. s. i.	75,000 lbs. p. s. i. min.	90,000 lbs. p. s. i. min.
Elongation in 2 in.	25%	25% min.	18% min.

Designers faced with the task of reducing the weight of structural members will find in Republic Double Strength Steels a valuable aid. They make one pound of steel do the work of two.

Compare their physical properties with those of ordinary carbon steel, and it is easily apparent that sheets, strip and plates 30% to 40% lighter may be used safely without sacrifice of strength. And tempering increases their yield points an additional 20,000 to 30,000 pounds. Ductility is excellent. They can be arc, gas or spot welded. And because of their copper, nickel and molybdenum content, they resist corrosion and show a life equal to or greater than the heavier sections of carbon steel now in general use.

These steels mean more economical operation for owners of trucks, buses and pleasure cars. Let us help you to be among the first to give your customers the benefits these new steels will bring. Write for information.

Republic Steel
CORPORATION
GENERAL OFFICES · · · YOUNGSTOWN, OHIO
CENTRAL ALLOY DIVISION · · MASSILLON, OHIO

ACOUSTICAL TREATMENT
for STEEL TRUCK CABS

A New Application of Burgess Sound Treatment

Noises caused by drumming and vibration in steel cabs have been effectively reduced in a series of trucks built by Chrysler Corporation, Dodge Division, for Standard Oil of New Jersey. The cab interiors are lined with Burgess perforated metal backed by a sound absorbing material. The result is a hard, durable, smooth surface, a reduction in vibration and the same sound absorption as if the cab were upholstered throughout.

Another BURGESS *Achievment*

This latest adaptation of Burgess-Acoustic Metal is further proof of the correctness of the Burgess principle of sound absorption through perforated metal, used in Burgess-Acoustic Straight-Thru Mufflers and Silencers. It is evidence too of the cooperation extended to designers and engineers in the solution of acoustic problems

BURGESS
ACOUSTIC

ACOUSTIC DIVISION
BURGESS BATTERY CO.

MAIN OFFICE MADISON, WISCONSIN DETROIT OFFICE 542 NEW CENTER BLDG.

NOTES AND REVIEWS

Continued

ENGINES

Automobile and Aircraft Engines

By Arthur W. Judge. Published by Sir Isaac Pitman & Sons, Ltd., New York and London, Third Edition, 1934; 890 pp., illustrated. [E-1]

Originally published about twenty years ago, this work has been reprinted and revised several times to keep pace with progress; the last previous edition appeared some three years ago.

A full account of the high speed compression-ignition engine is given together with many detailed improvements and new materials developed since the last revision of this book.

A Description and Test Results of a Spark-Ignition and Compression-Ignition 2-Stroke-Cycle Engine

By J. A. Spanogle and E. G. Whitney. N.A.C.A. Report No. 495, 1934; 19 pp., illustrated. Price, 10 cents. [E-1]

Causes of Detonation in Petrol and Diesel Engines

By G. D. Boerlage and W. J. D. Van Dyck. Published in *The Journal of The Royal Aeronautical Society*, December, 1934, p. 953. [E-1]

The authors put forward the view that it is correct to look at the phenomena of combustion in Diesel engines and in gasoline engines from the same aspect. In both cases the number of collisions of activated reagents is decisive, and self-ignition may be influenced equally by activated oxygen as by activated hydro-carbon. It cannot be overlooked that in the gasoline engine unstable peroxide-like compounds formed early during the compression stroke may have some influence; their effect will at most produce an effect on the main phenomenon of auto-ignition of the end gas under Diesel conditions. It is pointed out that "detonation" or "pink" may occur in any class of engine, and is a vibration in the air charge due to a local rapid pressure-rise. As such it is most commonly met in a pinking gasoline engine, but it occurs also in Diesel engines. On the other hand, "knock" indicates mechanical vibration, mainly of walls, due to a rapid pressure-rise, and is inherent to the gasoline pink as well as, in many cases, to the Diesel process. The term "bumpy running" may be reserved finally for those cases where heavy engine parts, i.e., crankshaft, are set in vibration.

Modern Carburetion

By Charles H. Fisher. Published in *The Automobile Engineer*, January, 1935, p. 15. [E-1]

As regards the relation between thermal efficiency and carburetion in terms of road performance, a comparison between the efficiencies developed by the carburetor engine and those of the compression ignition engine, the author points out, the former shows some disadvantage where the matters of thermal efficiency and economy are concerned. This article reviews briefly the reasons for the discrepancy and suggests lines of attack toward effecting improvement.

Effect of Combustion-Chamber Shape on the Performance of a Prechamber Compression-Ignition Engine

C. S. Moore and J. H. Collins, Jr. N.A.C.A. Technical Note No. 514, December, 1934; 15 pp., 11 figs. [E-1]

The Heat Transfer of Cooling Fins on Moving Air

By Hans Doetsch. Translated from Abhandlungen aus dem Aerodynamischen Institut an der Technischen Hochschule Aachen, No. 14, 1934. N.A.C.A. Technical Memorandum No. 763, January, 1935; 29 pp., 29 figs. [E-1]

Les Pistons et les Culasses en Alliages d'Aluminium

By Henri Petit. Published in *La Technique Automobile et Aérienne*, 1st quarter, 1935, p. 1. [E-1]

First, the ability to diffuse among its entire mass heat generated at particular points and, second, thermal conductivity are the qualities which recommend aluminum alloys as piston and combustion chamber material. Thermal expansion and the maintenance of physical properties at high temperatures present the problems that must be solved if these metals are to be successfully used. Expanding on these points, the author points out the advantages of aluminum pistons and combustion chambers, describes some of the expedients for overcoming the difficulties involved in the use of aluminum alloys and sets forth the chemical composition and physical properties of the principal alloys used for pistons.

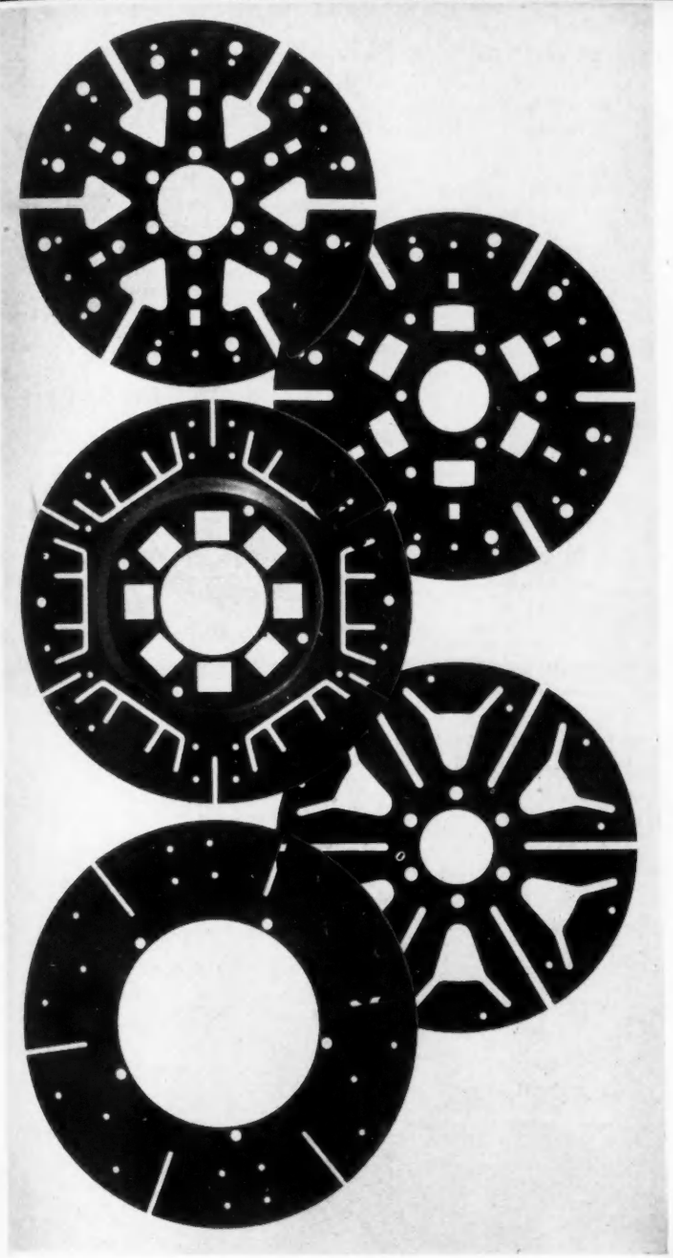
Application des Moteurs Thermiques à Injection Mecanique à la Traction sur Voies Ferrées

By M. Royer and J. Trollux. Published in *La Technique Moderne*, Feb. 1, 1935, p. 65. [E-1]

That Diesel engine propulsion on the railways may be considered

(Continued on page 44)

INGERSOLL CLUTCH PLATES



"A BORG-WARNER PRODUCT"

The interlocking mesh-grain structure of the special heat-treated steel used gives to these plates—

Greater Smoothness
More Flexibility
Longer Life

●

The majority of cars today are equipped with clutch plates made from Ingersoll TEM-CROSS Steel—a proven product that meets perfectly the dependability requirements of clutch operation.

Made Exclusively from

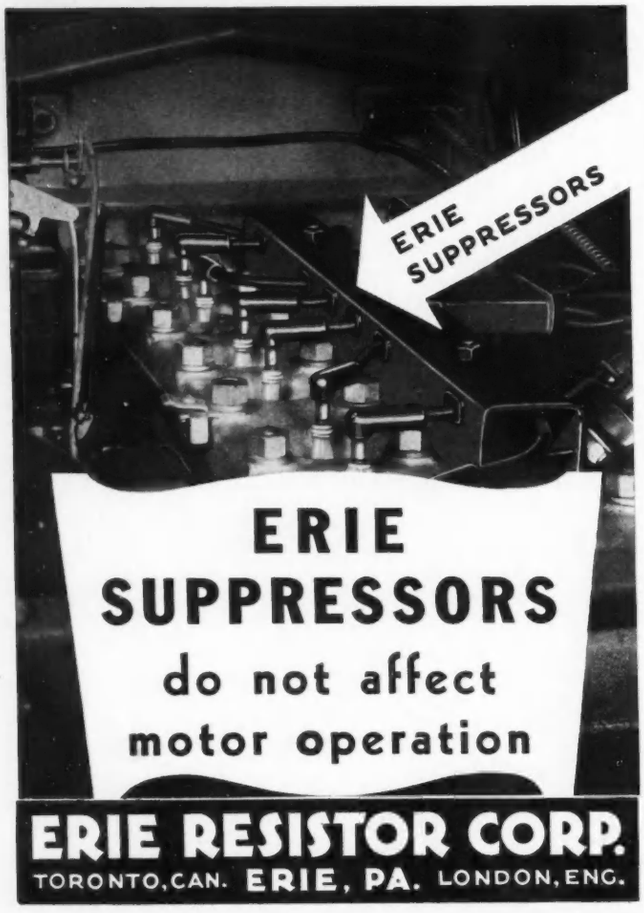
TEM-CROSS Trade Mark
INGERSOLL PROCESS STEEL

INQUIRIES ARE INVITED

INGERSOLL STEEL & DISC CO.

Division of Borg-Warner Corporation
NEW CASTLE, INDIANA

Plants: New Castle, Indiana . . . Chicago, Illinois



NOTES AND REVIEWS

Concluded

as a present reality susceptible of future development is the opinion here expressed. The present status of Diesel engine usage on railways, the design of such engines, the methods of adapting various transmission systems to their operation characteristics and recent progress along these lines in France constitute the subject matter of a series of articles of which this is the first.

MATERIAL

A New Method for Measuring Corrosion of Metals

By W. R. van Wijk. Published in *Industrial and Engineering Chemistry*, Analytical Edition, January 15, 1935, p. 48. [G-1]

The need for a method of measuring corrosion of metals whereby even the slightest corrosion can be measured quantitatively with great accuracy under normal conditions and within a reasonable time is emphasized and the author contends that such a method has now been developed by subliming extremely thin layers of metal on glass plaques in high vacuum and measuring their thickness before and after subjecting them to corrosive action, the measurements being made by determining the coefficient of the light-transmissibility of the metal-coated plaques. Owing to the high absorption coefficient of metals, it is said to be possible, with an optical apparatus of great precision, to measure a change in thickness of even one atomic diameter.

MISCELLANEOUS

Errata [H-1]

On page 32 of the April issue of the S.A.E. JOURNAL *the review of Dr. John Gaillard's book was incorrectly titled. It should have appeared as follows:*

Industrial Standardization, Its Principles and Application

By John Gaillard. Published by The H. W. Wilson Co., New York, 1935; 193 pp.

NEW SPICER NEEDLE BEARING SHORT-COUPLED JOINTS
now available in all sizes and shorter lengths

SPICER MANUFACTURING CORPORATION, TOLEDO, OHIO

BROWN-LIPE CLUTCHES and TRANSMISSIONS
SALISBURY FRONT and REAR AXLES
SPICER UNIVERSAL JOINTS
PARISH FRAMES READING, PA.